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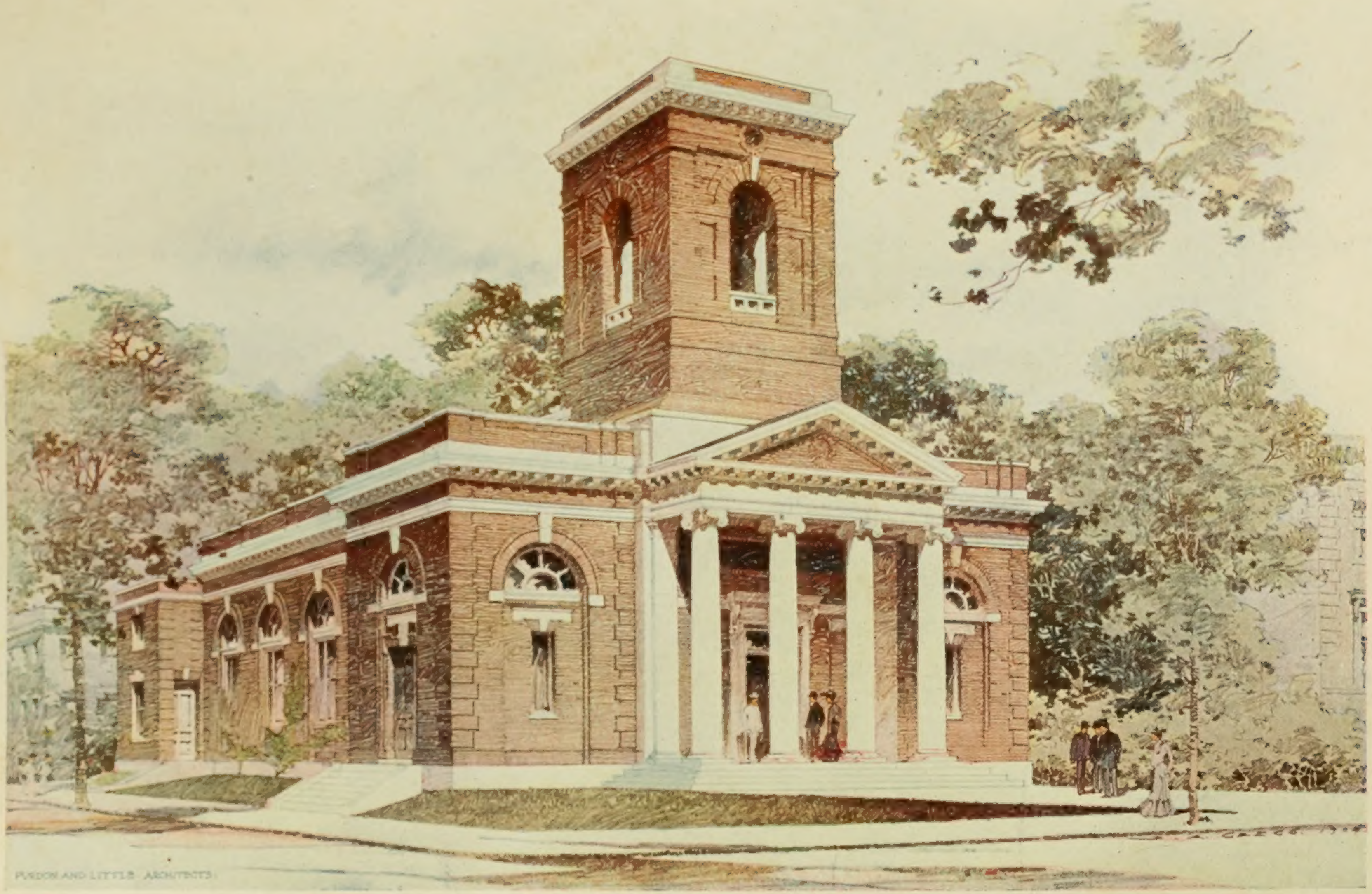

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Cyclopedia
of
Architecture, Carpentry and Building

A General Reference Work

ON ARCHITECTURE, CARPENTRY, BUILDING, SUPERINTENDENCE,
CONTRACTS, SPECIFICATIONS, BUILDING LAW, STAIR-BUILDING,
ESTIMATING, MASONRY, REINFORCED CONCRETE, STEEL
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Prepared by a Staff of

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Grateful acknowledgment is here made also for the invaluable cooperation of the foremost architects, engineers, and builders in making these volumes thoroughly representative of the very best and latest practice in the design and construction of buildings; also for the valuable drawings and data, suggestions, criticisms, and other courtesies.

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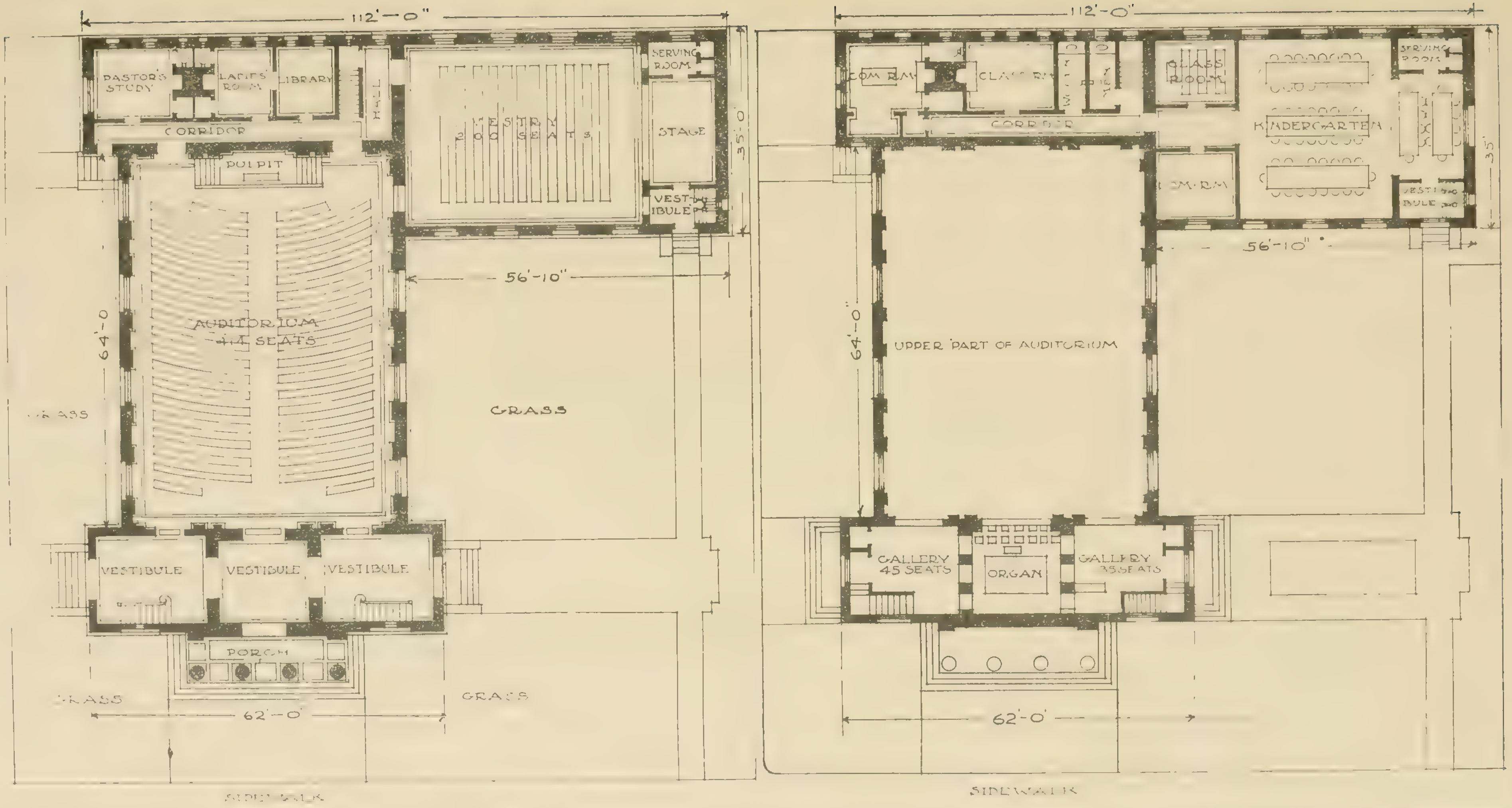

PLAN OF THE CHURCH OF THE DISCIPLES, BOSTON, MASS.

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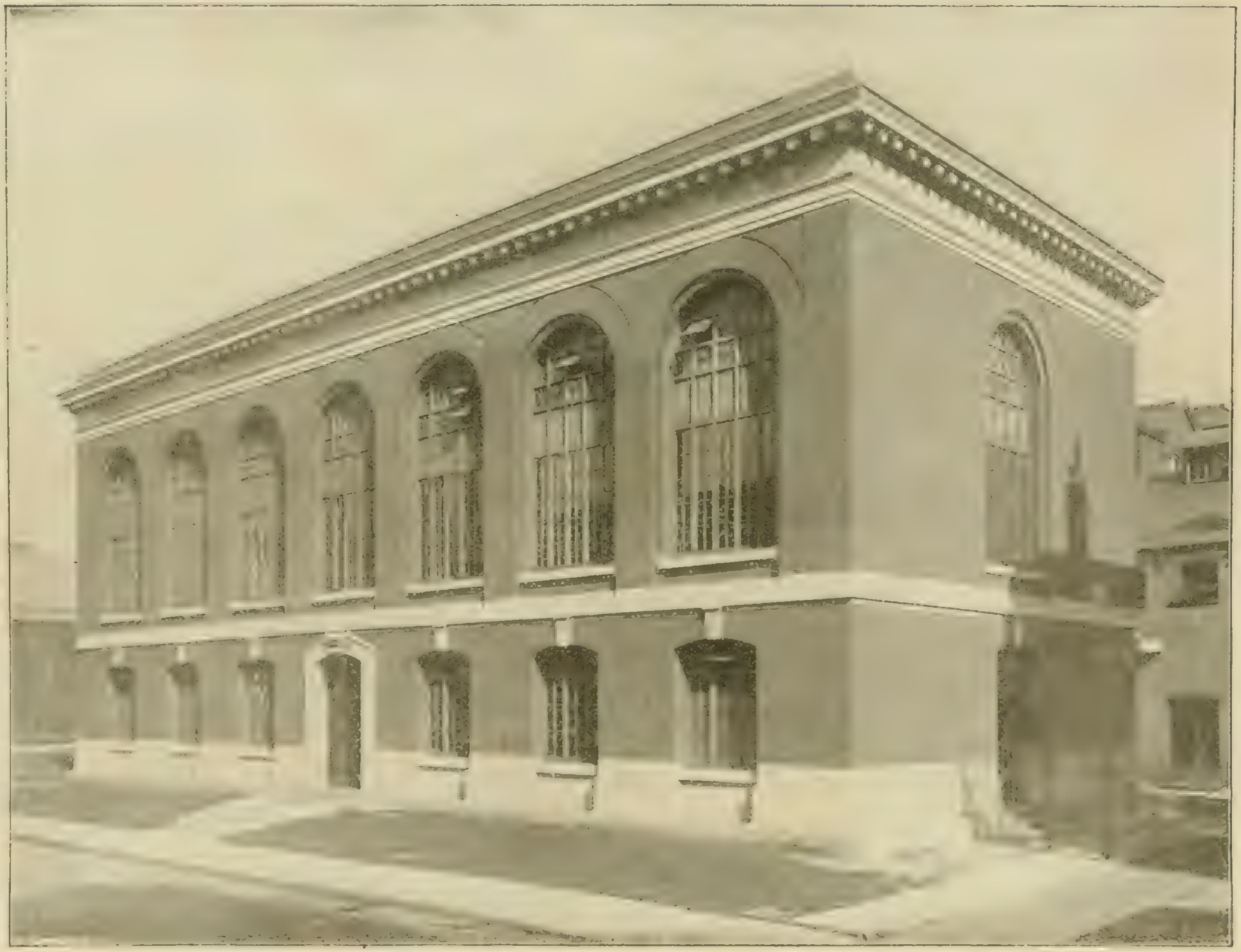

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Foreword

THE rapid evolution of constructive methods in recent years, as illustrated in the use of steel and concrete, and the increased size and complexity of buildings, has created the necessity for an authority which shall embody accumulated experience and approved practice along a variety of correlated lines. The Cyclopedia of Architecture, Carpentry, and Building is designed to fill this acknowledged need.

❡ There is no industry that compares with Building in the close interdependence of its subsidiary trades. The Architect, for example, who knows nothing of Steel or Concrete construction is to-day as much out of place on important work as the Contractor who cannot make intelligent estimates, or who understands nothing of his legal rights and responsibilities. A carpenter must now know something of Masonry, Electric Wiring, and, in fact, all other trades employed in the erection of a building; and the same is true of all the craftsmen whose handiwork will enter into the completed structure.

❡ Neither pains nor expense have been spared to make the present work the most comprehensive and authoritative on the subject of Building and its allied industries. The aim has been, not merely to create a work which will appeal to the trained expert, but one that will commend itself also to the beginner and the self-taught, practical man by giving him a working knowledge of the principles and methods, not only of his own particular trade, but of all other branches of the Building Industry as well. The various sections have been prepared especially for home study, each written by an acknowledged authority on the subject. The arrangement of matter is such as to carry the student forward by easy stages. Series of review questions are inserted in each volume, enabling the reader to test his knowledge and make it a permanent possession. The illustrations have been selected with unusual care to elucidate the text.

¶ The work will be found to cover many important topics on which little information has heretofore been available. This is especially apparent in such sections as those on Steel, Concrete, and Reinforced Concrete Construction; Building Superintendence; Estimating; Contracts and Specifications, including the principles and methods of awarding and executing Government contracts; and Building Law.

¶ The method adopted in the preparation of the work is that which the American School of Correspondence has developed and employed so successfully for many years. It is not an experiment, but has stood the severest of all tests—that of practical use—which has demonstrated it to be the best method yet devised for the education of the busy working man.

¶ In conclusion, grateful acknowledgment is due the staff of authors and collaborators, without whose hearty co-operation this work would have been impossible.

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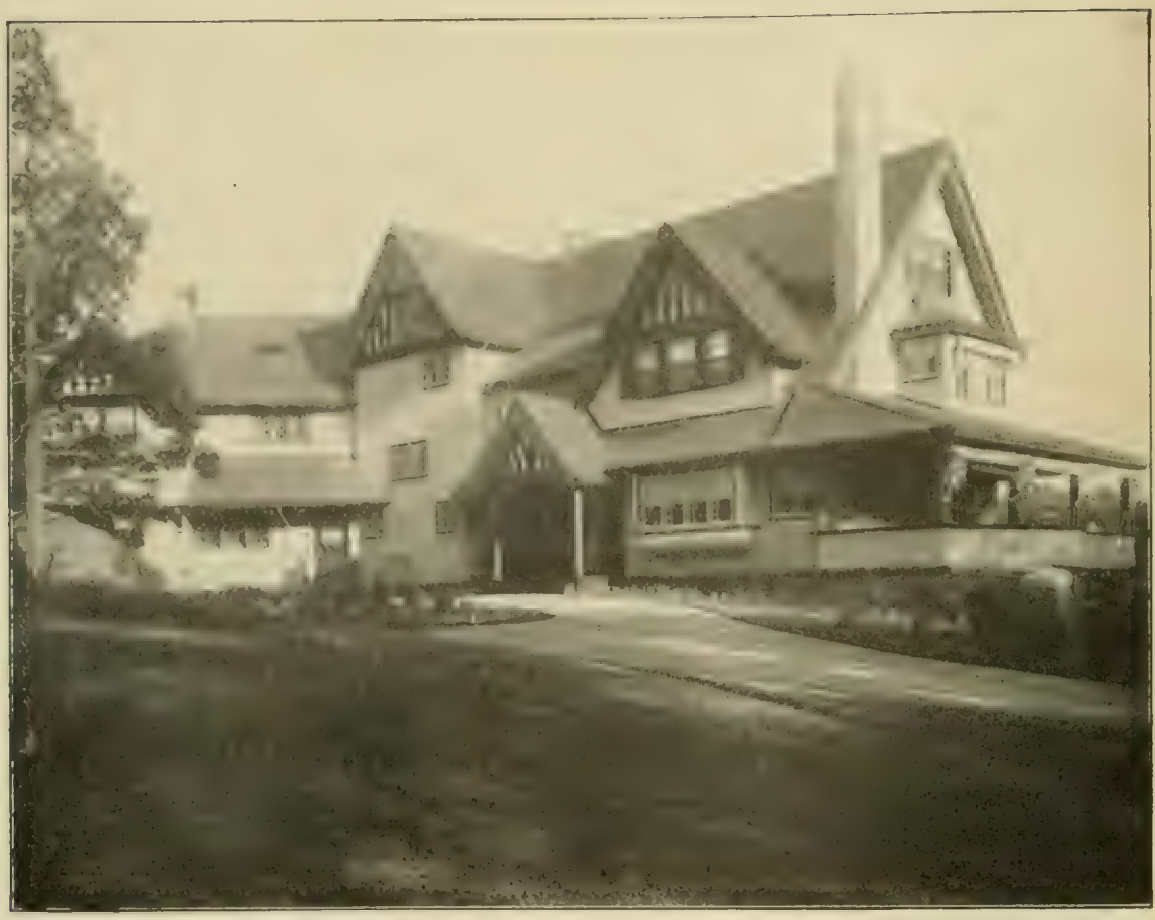

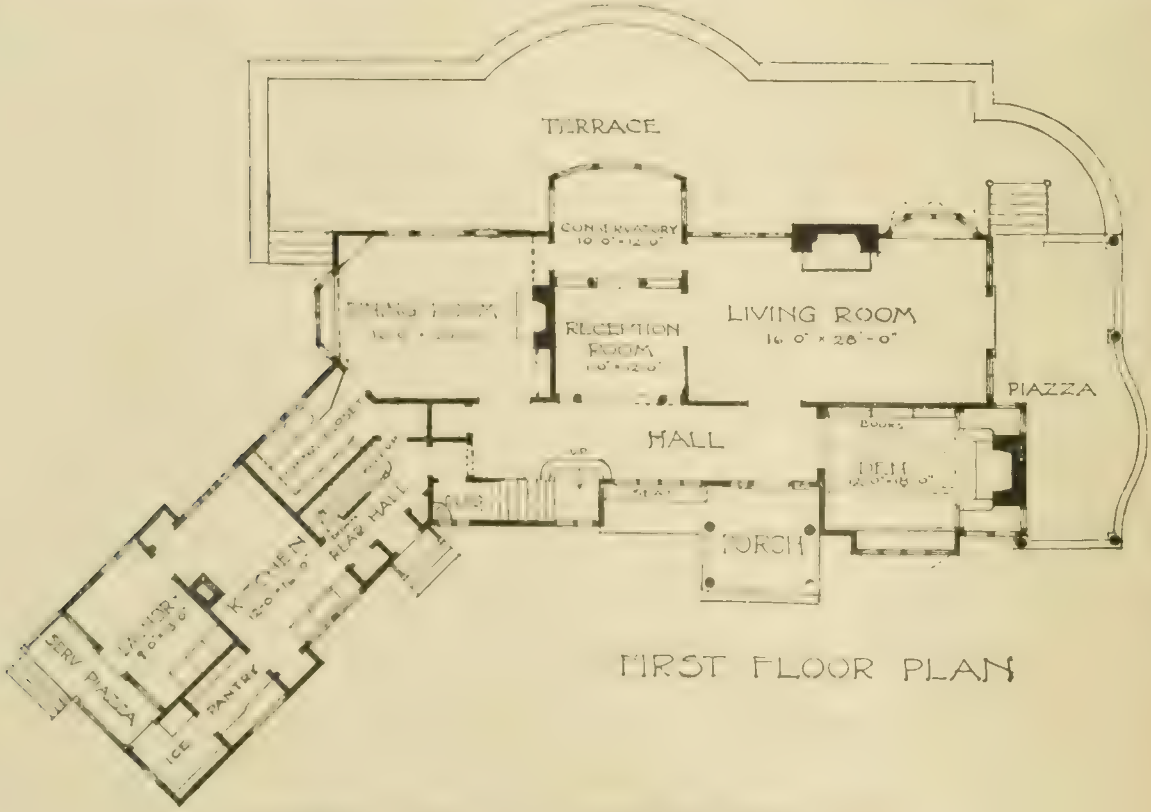

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HEATING AND VENTILATION

PART I

SYSTEMS OF WARMING

Any system of warming must include, *first*, the combustion of fuel, which may take place in a fireplace, stove, or furnace, or a steam, or hot-water boiler; *second*, a system of transmission, by means of which the heat may be carried, with as little loss as possible, to the place where it is to be used for warming; and *third*, a system of diffusion, which will convey the heat to the air in a room, and to its walls, floors, etc., in the most economical way.

Stoves. The simplest and cheapest form of heating is the stove. The heat is diffused by radiation and convection directly to the objects and air in the room, and no special system of transmission is required. The stove is used largely in the country, and is especially adapted to the warming of small dwelling-houses and isolated rooms.

Furnaces. Next in cost of installation and in simplicity of operation, is the hot-air furnace. In this method, the air is drawn over heated surfaces and then transmitted through pipes, while at a high temperature, to the rooms where heat is required. Furnaces are used largely for warming dwelling-houses, also churches, halls, and schoolhouses of small size. They are more costly than stoves, but have certain advantages over that form of heating. They require less care, as several rooms may be warmed from a single furnace; and, being placed in the basement, more space is available in the rooms above, and the dirt and litter connected with the care of a stove are largely done away with. They require less care, as only one fire is necessary to warm all the rooms in a house of ordinary size. One great advantage in the furnace method of warming comes from the constant supply of fresh air which is required to bring the heat into the rooms. While this is greatly to be desired from a sanitary standpoint, it calls for the consumption of a larger amount of fuel than would otherwise be necessary. This is true because heat is required to warm the fresh air from out of doors up to the temperature of the rooms, in addition to replacing the heat lost by leakage and conduction through walls and windows.

A more even temperature may be maintained with a furnace than by the use of stoves, owing to the greater depth and size of the fire, which allows it to be more easily controlled.

When a building is placed in an exposed location, there is often difficulty in warming rooms on the north and west sides, or on that side toward the prevailing winds. This may be overcome to some extent by a proper location of the furnace and by the use of extra large pipes for conveying the hot air to those rooms requiring special attention.

Direct Steam. Direct steam, so called, is widely used in all classes of buildings, both by itself and in combination with other systems. The first cost of installation is greater than for a furnace; but the amount of fuel required is less, as no outside air supply is necessary. If used for warming hospitals, schoolhouses, or other buildings where a generous supply of fresh air is desired, this method must be supplemented by some form of ventilating system.

One of the principal advantages of direct steam is the ability to heat all rooms alike, regardless of their location or of the action of winds.

When compared with hot-water heating, it has still another desirable feature—which is its freedom from damage by the freezing of water in the radiators when closed, which is likely to happen in unused rooms during very cold weather in the case of the former system.

On the other hand, the sizes of the radiators must be proportioned for warming the rooms in the coldest weather, and unfortunately there is no satisfactory method of regulating the amount of heat in mild weather, except by shutting off or turning on steam in the radiators at more or less frequent intervals as may be required, unless one of the expensive systems of automatic control is employed. In large rooms, a certain amount of regulation can be secured by dividing the radiation into two or more parts, so that different combinations may be used under varying conditions of outside temperature. If two radiators are used, their surface should be proportioned, when convenient, in the ratio of 1 to 2, in which case one-third, two-thirds, or the whole power of the radiation can be used as desired.

Indirect Steam. This system of heating combines some of the advantages of both the furnace and direct steam, but is more costly to install than either of these. The amount of fuel required is about the same as for furnace heating, because in each case the cool fresh air must be warmed up to the temperature of the room, before it can become a medium for conveying heat to offset that lost by leakage and conduction through walls and windows.

A system for indirect steam may be so designed that it will supply a greater quantity of fresh air than the ordinary form of furnace, in which case the cost of fuel will of course be increased in proportion to the volume of air supplied. Instead of placing the radiators in the rooms, a special form of heater is supported near the basement ceiling and encased in either galvanized iron or brick. A cold-air supply duct is connected with the space below the heater, and warm air pipes are taken from the top and connected with registers in the rooms to be heated the same as in the case of furnace heating.

A separate stack or heater may be provided for each register if the rooms are large; but, if small and so located that they may be reached by short runs of horizontal pipe, a single heater may serve for two or more rooms.

The advantage of indirect steam over furnace heating comes from the fact that the stacks may be placed at or near the bases of the flues leading to the different rooms, thus doing away with long, horizontal runs of pipe, and counteracting to a considerable extent the effect of wind pressure upon exposed rooms. Indirect and direct heating are often combined to advantage by using the former for the more important rooms, where ventilation is desired, and the latter for rooms more remote or where heat only is required.

Another advantage is the large ratio between the radiating surface and grate-area, as compared with a furnace; this results in a large volume of air being warmed to a moderate temperature instead of a smaller quantity being heated to a much higher temperature, thus giving a more agreeable quality to the air and rendering it less dry.

Indirect steam is adapted to all the buildings mentioned in connection with furnace heating, and may be used to much better advantage in those of large size. This applies especially to cases where more than one furnace is necessary; for, with steam heat, a single boiler, or a battery of boilers, may be made to supply heat for a building of any size, or for a group of several buildings, if desired, and is much easier to care for than several furnaces widely scattered.

Direct-Indirect Radiators. These radiators are placed in the room the same as the ordinary direct type. The construction is such that when the sections are in place, small flues are formed between them; and air, being admitted through an opening in the outside wall, passes upward through them and becomes heated before entering the room. A switch damper is placed in the casing at the base of the radiator, so that air may be taken from the room itself instead of from out of doors, if so desired. Radiators of this kind are not used to any great extent, as there is likely to be more or less leakage of cold air into the room around the base. If ventilation is required, it is better to use the regular form of indirect heater with flue and register, if possible. It is sometimes desirable to partially ventilate an isolated room where it would be impossible to run a flue, and in cases of this kind the direct-indirect form is often useful.

Direct Hot Water. Hot water is especially adapted to the warming of dwellings and greenhouses, owing to the ease with which the temperature can be regulated. When steam is used, the radiators are always at practically the same temperature, while with hot water the temperature can be varied at will. A system for hot-water heating costs more to install than one for steam, as the radiators must be larger and the pipes more carefully run. On the other hand, the cost of operating is somewhat less, because the water need be carried only at a temperature sufficiently high to warm the rooms properly in mild weather, while with steam the building is likely to become overheated, and more or less heat wasted through open doors and windows.

A comparison of the relative costs of installing and operating hot-air, steam, and hot-water systems, is given in Table I.

TABLE I

Relative Cost of Heating Systems

	HOT AIR	STEAM	HOT WATER
Relative cost of apparatus	9	13	15
Relative cost, adding repairs and fuel for five years	29½	29¾	27
Relative cost, adding repairs and fuel for fifteen years	81	63	52½

One disadvantage in the use of hot water is the danger from freezing when radiators are shut off in unused rooms. This makes it necessary in very cold weather to have all parts of the system turned on sufficiently to produce a circulation, even if very slow. This is sometimes accomplished by drilling a very small hole (about $\frac{1}{8}$ inch) in the valve-seat, to that when closed there will still be a very slow circulation through the radiator, thus preventing the temperature of the water from reaching the freezing point.

Indirect Hot Water. This is used under the same conditions as indirect steam, but more especially in the case of dwellings and hospitals. When applied to other and larger buildings, it is customary to force the water through the mains by means of a pump. Larger heating stacks and supply pipes are required than for steam; but the arrangement and size of air-flues and registers are practically the same, although they are sometimes made slightly larger in special cases.

Exhaust Steam. Exhaust steam is used for heating in connection with power plants, as in shops and factories, or in office buildings which have their own lighting plants. There are two methods of using exhaust steam for heating purposes. One is to carry a back pressure of 2 to 5 pounds on the engines, depending upon the length and size of the pipe mains; and the other is to use some form of *vacuum system* attached to the returns or air-valves, which tends to reduce the back pressure rather than to increase it.

Where the first method is used and a back pressure carried, either the boiler pressure or the cut-off of the engines must be increased, to keep the mean effective pressure the same and not reduce the horse-power delivered. In general it is more economical to utilize the exhaust steam for heating. There are instances, however, where the relation between the quantities of steam required for heating and for power are such—especially if the engines are run condensing—that it is better to throw the exhaust away and heat with live steam. Where the vacuum method is used, these difficulties are avoided; and for this reason that method is coming into quite common use. If the condensation from the exhaust steam is returned to the boilers, the oil must first be removed; this is usually accomplished by passing the steam through some form of grease extractor as it leaves the engine. The water of condensation is often passed through a separating tank in addition to this, before it is delivered to the return pumps. It is better, however, to remove a portion of the oil before the steam enters the heating system; otherwise a coating will be formed upon the inner surfaces of the radiators, which will reduce their efficiency to some extent.

Forced Blast. This method of heating, in different forms, is used for the warming of factories, schools, churches, theaters, halls—in fact, any large building where good ventilation is desired. The air for warming is drawn or forced through a heater of special design, and discharged by a fan or blower into ducts which lead to registers placed in the rooms to be warmed. The heater is usually made up in sections, so that steam may be admitted to or shut off from any section independently of the others, and the temperature of the air regulated in this manner. Sometimes a *by-pass damper* is attached, so that part of the air will pass through the heater and part around or over it; in this way the proportions of cold and heated air may be so adjusted as to give the desired temperature to the air entering the rooms. These forms of regulation are common where a blower is used for warming a single room, as in the case of a church or hall; but where several rooms are warmed, as in a schoolhouse, it is customary to use the main or primary heater at the blower for warming the air to a given temperature (somewhat below that which is actually required), and to supplement this by placing secondary coils or heaters at the bottoms of the flues leading to the different rooms. By means of this arrangement, the temperature of each room can be regulated independently of the others. The so-called *double-duct* system is sometimes employed. In this case, two ducts are carried to each register, one supplying hot air and the other cold or tempered air; and a damper for mixing these in the right proportions is placed in the flue, below the register.

Electric Heating. Unless electricity can be produced at a very low cost, it is not practicable for heating residences or large buildings. The electric heater, however, has quite a wide field of application in heating small offices, bathrooms, electric cars, etc. It is a convenient method of warming isolated rooms on cold mornings, in late spring and early fall, when the regular heating apparatus of the building is not in operation. It has the advantage of being instantly available, and the amount of heat can be regulated at will. Electric heaters are clean, do not vitiate the air, and are easily moved from place to place.

PRINCIPLES OF VENTILATION

Closely connected with the subject of heating is the problem of maintaining air of a certain standard of purity in the various buildings occupied.

The introduction of pure air can be done properly only in connection with some system of heating; and no system of heating is complete without a supply of pure air, depending in amount upon the kind of building and the purpose for which it is used.

Composition of the Atmosphere. Atmospheric air is not a simple substance but a mechanical mixture. Oxygen and nitrogen, the principal constituents, are present in very nearly the proportion of one part of oxygen to four parts of nitrogen by weight. Carbonic acid gas, the product of all combustion, exists in the proportion of 3 to 5 parts in 10,000 in the open country. Water in the form of vapor, varies greatly with the temperature and with the exposure of the air to open bodies of water. In addition to the above, there are generally present, in variable but exceedingly small quantities, ammonia, sulphuretted hydrogen, sulphuric, sulphurous, nitric, and nitrous acids, floating organic and inorganic matter, and local impurities. Air also contains ozone, which is a peculiarly active form of oxygen; and lately another constituent called *argon* has been discovered.

Oxygen is the most important element of the air, so far as both heating and ventilation are concerned. It is the active element in the chemical process of combustion and also in the somewhat similar process which takes place in the respiration of human beings. Taken into the lungs, it acts upon the excess of carbon in the blood, and possibly upon other ingredients, forming chemical compounds which are thrown off in the act of respiration or breathing.

Nitrogen. The principal bulk of the atmosphere is nitrogen, which exists uniformly diffused with oxygen and carbonic acid gas. This element is practically inert in all processes of combustion or respiration. It is not affected in composition, either by passing through a furnace during combustion or through the lungs in the process of respiration. Its action is to render the oxygen less active, and to absorb some part of the heat produced by the process of oxidation.

Carbonic acid gas is of itself only a neutral constituent of the atmosphere, like nitrogen; and—contrary to the general impression—its presence in moderately large quantities (if uncombined with other substances) is neither disagreeable nor especially harmful. Its presence, however, in air provided for respiration, decreases the readiness with which the carbon of the blood unites with the oxygen of the air; and therefore, when present in sufficient quantity, it may cause indirectly, not only serious, but fatal results. The real harm of a vitiated atmosphere, however, is caused by the other constituent gases and by the minute organisms which are produced in the process of respiration. It is known that these other impurities exist in fixed proportion to the amount of carbonic acid present in an atmosphere vitiated by respiration. Therefore, as the relative proportion of carbonic acid can easily be determined by experiment, the fixing of a standard limit of the amount in which it may be allowed, also limits the amounts of other impurities which are found in combination with it.

When carbonic acid is present in excess of 10 parts in 10,000 parts of air, a feeling of weariness and stuffiness, generally accompanied by a headache, will be experienced; while with even 8 parts in 10,000 parts a room would be considered close. For general considerations of ventilation, the limit should be placed at 6 to 7 parts in 10,000, thus allowing an increase of 2 to 3 parts over that present in outdoor air, which may be considered to contain four parts in 10,000 under ordinary conditions.

Analysis of Air. An accurate qualitative and quantitative analysis of air samples can be made only by an experienced chemist. There are, however, several approximate methods for determining the amount of carbonic acid present, which are sufficiently exact for practical purposes. Among these the following is one of the simplest:

The necessary apparatus consists of six clean, dry, and tightly corked bottles, containing respectively 100, 200, 250, 300, 350, and 400 cubic centimeters, a glass tube containing exactly 15 cubic centimeters to a given mark, and a bottle of perfectly clear, fresh limewater. The bottles should be filled with the air to be examined by means of a hand-ball syringe. Add to the smallest bottle 15 cubic centimeters of the limewater, put in the cork, and shake well. If the limewater has a milky appearance, the amount of carbonic acid will be at least 16 parts in 10,000. If the contents of the bottle remain clear, treat the bottle of 200 cubic centimeters in the same manner; a milky appearance or turbidity in this would indicate 12 parts in 10,000. In a similar manner, turbidity in the 250 cubic centimeter bottle indicates

10 parts in 10,000; in the 300, 8 parts; in the 350, 7 parts; and in the 400, less than 6 parts. The ability to conduct more accurate analyses can be attained only by special study and a knowledge of chemical properties and of methods of investigation.

Another method similar to the above, makes use of a glass cylinder containing a given quantity of limewater and provided with a piston. A sample of the air to be tested is drawn into the cylinder by an upward movement of the piston. The cylinder is then thoroughly shaken, and if the limewater shows a milky appearance, it indicates a certain proportion of carbonic acid in the air. If the limewater remains clear, the air is forced out, and another cylinder full drawn in, the operation being repeated until the limewater becomes milky. The size of the cylinder and the quantity of limewater are so proportioned that a change in color at the first, second, third, etc., cylinder full of air indicates different proportions of carbonic acid. This test is really the same in principle as the one previously described; but the apparatus used is in more convenient form.

Air Required for Ventilation. The amount of air required to maintain any given standard of purity can very easily be determined, provided we know the amount of carbonic acid given off in the process of respiration. It has been found by experiment that the average production of carbonic acid by an adult at rest is about .6 cubic foot per hour. If we assume the proportion of this gas as 4 parts in 10,000 in the external air, and are to allow 6 parts in 10,000 in an occupied room, the gain will be 2 parts in 10,000; or, in other words, there will be $\frac{2}{10,000} = .0002$ cubic foot of carbonic acid mixed with each cubic foot of fresh air entering the room. Therefore, if one person gives off .6 cubic foot of carbonic acid per hour, it will require $.6 \div .0002 = 3,000$ cubic feet of air per hour per person to keep the air in the room at the standard of purity assumed—that is, 6 parts of carbonic acid in 10,000 of air.

Table II has been computed in this manner, and shows the amount of air which must be introduced for each person in order to maintain various standards of purity.

While this table gives the theoretical quantities of air required for different standards of purity, and may be used as a guide, it will be better in actual practice to use quantities which experience has shown to give good results in different types of buildings. In auditoriums where the cubic space per individual is large, and in which the atmosphere is thoroughly fresh before the rooms are occupied, and the occupancy is of only two or three hours' duration, the air-supply may be reduced somewhat from the figures given below.

TABLE II

Quantity of Air Required per Person

Standard Parts of Carbonic Acid in 10,000 of Air in Room	Cubic Feet of Air Required per Person	
	Per Minute	Per Hour
5	100	6,000
6	50	3,000
7	33	2,000
8	25	1,500
9	20	1,200
10	16	1,000

Table III represents good modern practice and may be used with satisfactory results:

TABLE III

Air Required for Ventilation of Various Classes of Buildings

Air-Supply per Occupant for	Cubic Feet per Minute	Cubic Feet per Hour
Hospitals	80 to 100	4, 800 to 6, 000
High Schools	50	3, 000
Grammar Schools	40	2, 400
Theaters and Assembly Halls	25	1, 500
Churches	20	1, 200

When possible, the air-supply to any given room should be based upon the number of occupants. It sometimes happens, however, that this information is not available, or the character of the room is such that the number of persons occupying it may vary, as in the case of public waiting rooms, toilet rooms, etc. In instances of this kind, the required air-volume may be based upon the number of changes per hour. In using this method, various considerations must be taken into account, such as the use of the room and its condition as to crowding, character of occupants, etc. In general, the following will be found satisfactory for average conditions:

TABLE IV

Number of Changes of Air Required in Various Rooms

Use of Room	Changes of Air per Hour
Public Waiting Room	4 to 5
Public Toilets	5 " 6
Coat and Locker Rooms	4 " 5
Museums	3 " 4
Offices, Public	4 " 5
Offices, Private	3 " 4
Public Dining Rooms	4 " 5
Living Rooms	3 " 4
Libraries, Public	4 " 5
Libraries, Private	3 " 4

Force for Moving Air. Air is moved for ventilating purposes in two ways: (1) by expansion due to heating; (2) by mechanical means. The effect of heat on the air is to increase its volume and therefore lessen its density or weight, so that it tends to rise and is replaced by the colder air below. The available force for moving air obtained in this way is very small, and is quite likely to be overcome by wind or external causes. It will be found in general that the heat used for producing velocity in this manner, when transformed into work in the steam engine, is greatly in excess of that required to produce the same effect by the use of a fan.

Ventilation by mechanical means is performed either by pressure or by suction. The former is used for delivering fresh air into a building, and the latter for removing the foul air from it. By both processes the air is moved without change in temperature, and the force for moving must be sufficient to overcome the effects of wind or changes in outside temperature. Some form of fan is used for this purpose.

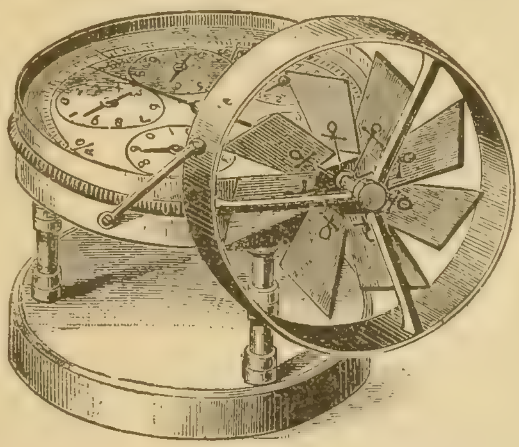


Fig. 1. Common Form of Anemometer, for Measuring Velocity of Air-Currents.

Measurements of Velocity. The velocity of air in ventilating ducts and flues is measured directly by an instrument called an anemometer. A common form of this instrument is shown in Fig. 1. It consists of a series of flat vanes attached to an axis, and a series of dials.

The revolution of the axis causes motion of the hands in proportion to the velocity of the air, and the result can be read directly from the dials for any given period.

For approximate results the anemometer may be slowly moved across the opening in either vertical or horizontal parallel lines, so that the readings will be made up of velocities taken from all parts of the opening. For more accurate work, the opening should be divided into a number of squares by means of small twine, and readings taken at the center of each. The mean of these readings will give the average velocity of the air through the entire opening.

AIR DISTRIBUTION

The location of the air inlet to a room depends upon the size of the room and the purpose for which it is used. In the case of living rooms in dwelling-houses, the registers are placed either in the floor or in the wall near the floor; this brings the warm air in at the coldest part of the room and gives an opportunity for warming or drying the feet if desired. In the case of schoolrooms, where large volumes of warm air at moderate temperatures are required, it is best to discharge it through openings in the wall at a height of 7 or 8 feet from the floor; this gives a more even distribution, as the warmer air tends to rise and hence spreads uniformly under the ceiling; it then gradually displaces other air, and the room becomes filled with pure air without sensible currents or drafts. The cooler air sinks to the bottom of the room, and can be taken off through ventilating registers placed near the floor. The relative positions of the inlet and outlet are often governed to some extent by the building construction; but, if possible, they should both be located in the same side of the room. Figs. 2, 3, and 4 show common arrangements.

The vent outlet should always, if possible, be placed in an inside wall; otherwise it will become chilled and the air-flow through it will become sluggish. In theaters and churches which are closely packed, the air should enter at or near the floor, in finely-divided streams; and the discharge ventilation should be through openings in the ceiling. The reason for this is the large amount of animal heat given off from the bodies of the audience; this causes the air to become still further heated after entering the room, and the tendency is to rise continuously from floor to ceiling, thus carrying away all impurities from respiration as fast as they are given off.

All audience halls in which the occupants are closely seated should be treated in the same manner, when possible. This, however, cannot always be done, as the seats are often made removable so that the floor can be used for other purposes. In cases of this kind, part of the air may be introduced through floor registers placed along the outer aisles, and the remainder by means of wall inlets the same as for schoolrooms. The discharge ventilation should be partly through registers near the floor, supplemented by ample ceiling vents for use when the hall is crowded or the outside temperature high.

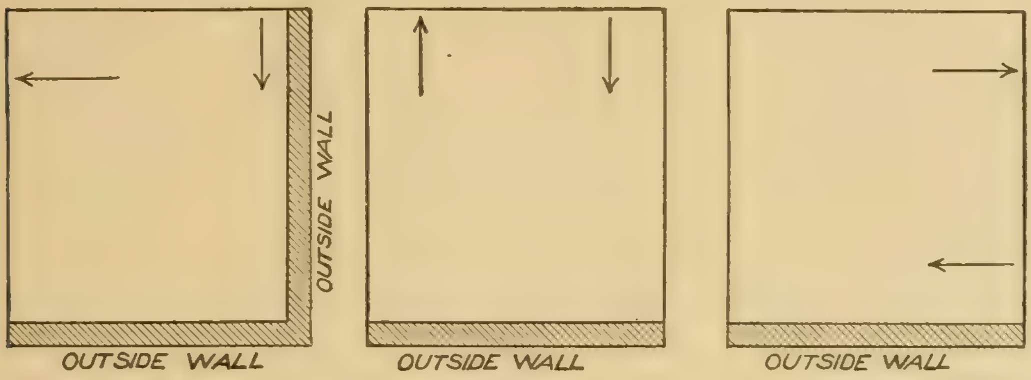


Fig. 2. Fig. 3. Fig. 4.

Diagrams Showing Relative Positions of Air Inlets and Outlets as Commonly Arranged.

The matter of air-velocities, size of flues, etc., will be taken up under the head of "Indirect Heating."

HEAT LOSS FROM BUILDINGS

A *British Thermal Unit,* or B. T. U., has been defined as the amount of heat required to raise the temperature of one pound of water one degree F. This measure of heat enters into many of the calculations involved in the solving of problems in heating and ventilation, and one should familiarize himself with the exact meaning of the term.

Causes of Heat Loss. The heat loss from a building is due to the following causes: (1) radiation and conduction of heat through walls and windows; (2) leakage of warm air around doors and windows and through the walls themselves; and (3) heat required to warm the air for ventilation.

Loss through Walls and Windows. The loss of heat through the walls of a building depends upon the material used in construction

TABLE V

Heat Losses in B. T. U. per Square Foot of Surface per Hour—Southern Exposure

MATERIAL	DIFFERENCE BETWEEN INSIDE AND OUTSIDE TEMPERATURES									
	10°	20°	30°	40°	50°	60°	70	80°	90°	100°
8-in. Brick Wall	5	9	13	18	22	27	31	36	40	45
12-in. Brick Wall	4	7	10	13	16	20	23	26	30	33
16-in. Brick Wall	3	5	8	10	13	16	19	22	24	27
20-in. Brick Wall	2.8	4.5	7	9	11	14	16	18	20	23
24-in. Brick Wall	2.5	4	6	8	10	12	14	16	18	20
28-in. Brick Wall	2	3.5	5	7	9	11	13	14	16	18
32-in. Brick Wall	1.5	3	4.5	6	8	10	11	13	15	16
Single Window	12	24	36	49	60	73	85	93	110	122
Double Window	8	16	24	32	40	48	56	62	70	78
Single Skylight	11	21	31	42	52	63	73	84	94	104
Double Skylight	7	14	20	28	35	42	48	56	62	70
1-in. Wooden Door	4	8	12	16	20	24	28	32	36	40
2-in. Wooden Door	3	5	8	11	14	17	20	23	25	28
2-in. Solid Plaster Partition	6	12	18	24	30	36	42	48	54	60
3-in. Solid Plaster Partition	5	10	15	20	25	30	35	40	45	50
Concrete Floor on Brick Arch	2	4	6.5	9	11	13	15	18	20	22
Wood Floor on Brick Arch	1.5	3	4.5	6	7	9	10	12	13	15
Double Wood Floor	1	2	3	4	5	6	7	8	9	10
Walls of Ordinary Wooden Dwellings	3	5	8	10	13	16	19	22	24	27

For *solid stone walls,* multiply the figures for brick of the same thickness by 1.7. Where rooms have a *cold attic above or cellar beneath,* multiply the heat loss through walls and windows by 1.1.

Correction for Leakage. The figures given in the above table apply only to the most thorough construction. For the average well-built house, the results should be increased about 10 per cent; for fairly good construction, 20 per cent; and for poor construction, 30 per cent.

Table V applies only to a southern exposure; for other exposures multiply the heat loss given in Table V by the factors given in Table VI.

of the wall, the thickness, the number of layers, and the difference between the inside and outside temperatures. The exact amount of heat lost in this way is very difficult to determine theoretically, hence we depend principally on the results of experiments.

Loss by Air-Leakage. The leakage of air from a room varies from one to two or more changes of the entire contents per hour, depending upon the construction, opening of doors, etc. It is common practice to allow for one change per hour in well-constructed buildings where two walls of the room have an outside exposure. As the amount of leakage depends upon the extent of exposed wall and window surface, the simplest way of providing for this is to increase

TABLE VI

Factors for Calculating Heat Loss for Other than Southern Exposures

Exposure	Factor
N.	1.32
E.	1.12
S.	1.0
W.	1.20
N. E.	1.22
N. W.	1.26
S. E.	1.06
S. W.	1.10
N., E., S., and W., or total exposure	1.16

the total loss through walls and windows by a factor depending upon the tightness of the building construction. Authorities differ considerably in the factors given for heat losses, and there are various methods for computing the same. The figures given in Table V have been used extensively in actual practice, and have been found to give good results when used with judgment. The table gives the heat losses through different thicknesses of walls, doors, windows, etc., in B. T. U., per square foot of surface per hour, for varying differences in inside and outside temperatures.

In computing the heat loss through walls, only those exposed to the outside air are considered.

In order to make the use of the table clear, we shall give a number of examples illustrating its use:

Example 1. Assuming an inside temperature of 70°, what will be the heat loss from a room having an exposed wall surface of 200 square feet and a glass surface of 50 square feet, when the outside temperature is zero? The wall is of brick, 16 inches in thickness, and has a southern exposure; the windows are single; and the construction is of the best, so that no account need be taken of leakage

We find from Table V, that the factor for a 16-inch brick wall with a difference in temperature of 70° is 19, and that for glass (single window) under the same condition is 85; therefore,

$$\begin{array}{lrl}
\text{Loss through walls} & = 200 \times 19 = & 3{,}800 \\
\text{Loss through windows} & = 50 \times 85 = & 4{,}250 \\
\hline
\text{Total loss per hour} & = & 8{,}050 \text{ B.T.U.}
\end{array}$$

Example 2. A room 15 ft. square and 10 ft. high has two exposed walls, one toward the north, and the other toward the west. There are 4 windows, each 3 feet by 6 feet in size. The two in the north wall are double, while the other two are single. The walls are of brick, 20 inches in thickness. With an inside temperature of 70°, what will be the heat loss per hour when it is 10° below zero?

Total exposed surface = 15 × 10 × 2 = 300

Glass surface = 3 × 6 × 4 = 72

Net wall surface = 228

Difference between inside and outside temperature 80°.

Factor for 20-inch brick wall is 18.

Factor for single window is 93.

Factor for double window is 62.

The heat losses are as follows:

Wall, 228 × 18 = 4,104

Single windows, 36 × 93 = 3,348

Double windows, 36 × 62 = 2,232

9,684 B. T. U.

As one side is toward the north, and the other toward the west, the actual exposure is N. W. Looking in Table VI, we find the correction factor for this exposure to be 1.26; therefore the total heat loss is

9,684 × 1.26 = 12,201.84 B. T. U.

Example 3. A dwelling-house of fair wooden construction measures 160 ft. around the outside; it has 2 stories, each 8 ft. in height; the windows are single, and the glass surface amounts to one-fifth the total exposure; the attic and cellar are unwarmed. If 8,000 B. T. U. are utilized from each pound of coal burned in the furnace, how many pounds will be required per hour to maintain a temperature of 70° when it is 20° above zero outside?

Total exposure 160 × 16 = 2,560

Glass surface = 2,560 ÷ 5 = 512

Net wall = 2,048

Temperature difference = 70 − 20 = 50°

Wall 2,048 × 13 = 26,624

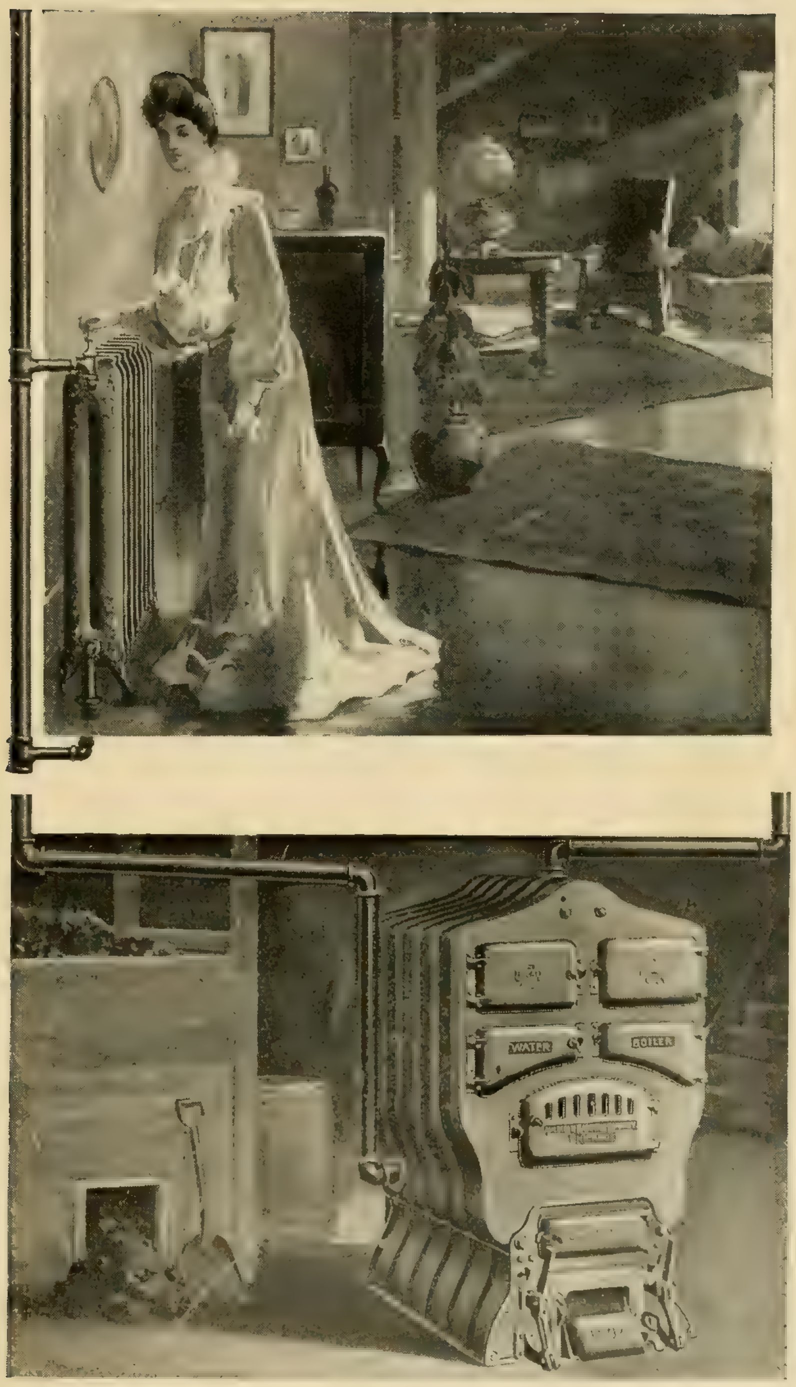
Glass 512 × 60 = 30,720

57,344 B. T. U.

As the building is exposed on all sides, the factor for exposure will be the average of those for N., E., S., and W., or

(1.32 + 1.12 + 1.0 + 1.20) ÷ 4 = 1 16

The house has a cold cellar and attic, so we must increase the heat loss



TYPICAL HEATING INSTALLATION SHOWING SECTIONAL BOILER AND RADIATOR.

American Radiator Company.

10 per cent for each of the first two conditions, and 20 per cent for the last. Making these corrections we have:

$$57{,}344 \times 1.16 \times 1.10 \times 1.10 \times 1.20 = 96{,}338 \text{ B. T. U.}$$

If one pound of coal furnishes 8,000 B. T. U., then 96,338 ÷ 8,000 = 12 pounds of coal per hour required to warm the building to 70° under the conditions stated.

Approximate Method. For dwelling-houses of the average construction, the following simple method for calculating the heat loss may be used. Multiply the total exposed surface by 45, which will give the heat loss in B. T. U. per hour for an inside temperature of 70° in zero weather.

This factor is obtained in the following manner: Assume the glass surface to be one-sixth the total exposure, which is an average proportion. Then each square foot of exposed surface consists one-sixth of glass and five-sixths of wall, and the heat loss for 70° difference in temperature would be as follows:

$$\text{Wall } \frac{5}{6} \times 19 = 15.8$$

$$\text{Glass } \frac{1}{6} \times 85 = \underline{14.1}$$

$$29.9$$

Increasing this 20 per cent for leakage, 16 per cent for exposure, and 10 per cent for cold ceilings, we have:

$$29.9 \times 1.20 \times 1.16 \times 1.10 = 45.$$

The loss through floors is considered as being offset by including the kitchen walls of a dwelling-house, which are warmed by the range, and which would not otherwise be included if computing the size of a furnace or boiler for heating.

If the heat loss is required for outside temperatures other than zero, multiply by 50 for 10 degrees below, and by 40 for 10 degrees above zero.

This method is convenient for approximations in the case of dwelling-houses; but the more exact method should be used for other types of buildings, and in all cases for computing the heating surface for separate rooms. *When calculating the heat loss from isolated rooms, the cold inside walls as well as the outside must be considered.*

The loss through a wall next to a cold attic or other unwarmed space may in general be taken as about two-thirds that of an outside wall.

Heat Loss by Ventilation. One B. T. U. will raise the temperature of 1 cubic foot of air 55 degrees at average temperatures and pressures, or will raise 55 cubic feet 1 degree, so that the heat required for the ventilation of any room can be found by the following formula:

$$\frac{\text{Cu. ft. of air per hour} \times \text{Number of degrees rise}}{55} = \text{B. T. U. required.}$$

To compute the heat loss for any given room which is to be ventilated, first find the loss through walls and windows, and correct for exposure and leakage; then compute the amount required for ventilation as above, and take the sum of the two. An inside temperature of 70° is always assumed unless otherwise stated.

Examples. What quantity of heat will be required to warm 100,000 cubic feet of air to 70° for ventilating purposes when the outside temperature is 10 below zero?

$$100{,}000 \times 80 \div 55 = 145{,}454 \text{ B. T. U.}$$

How many B. T. U. will be required per hour for the ventilation of a church seating 500 people, in zero weather?

Referring to Table III, we find that the total air required per hour is 1,200 × 500 = 600,000 cu. ft.; therefore 600,000 × 70 ÷ 55 = 763,636 B. T. U.

The factor $\frac{\text{Rise in Temperature}}{55}$ is approximately 1.1 for 60°, 1.3 for 70°, and 1.5 for 80°. Assuming a temperature of 70° for the entering air, we may multiply the air-volume supplied for ventilation by 1.1 for an outside temperature of 10° above 0, by 1.3 for zero, and by 1.5 for 10° below zero—which covers the conditions most commonly met with in practice.

EXAMPLES FOR PRACTICE

1. A room in a grammar school 28 ft. by 32 ft. and 12 feet high is to accommodate 50 pupils. The walls are of brick 16 inches in thickness; and there are 6 single windows in the room, each 3 ft. by 6 ft.; there are warm rooms above and below; the exposure is S. E. How many B. T. U. will be required per hour for warming the room, and how many for ventilation, in zero weather, assuming the building to be of average construction?

Ans. 24,261 + for warming; 152,727 + for ventilation.

2. A stone church seating 400 people has walls 20 inches in thickness. It has a wall exposure of 5,000 square feet, a glass expos-

ure (single windows) of 600 square feet, and a roof exposure of 7,000 square feet; the roof is of 2-inch pine plank, and the factor for heat loss may be taken the same as for a 2-inch wooden door. The floor is of wood on brick arches, and has an area of 4,000 square feet. The building is exposed on all sides, and is of first-class construction. What will be the heat required per hour for both warming and ventilation when the outside temperature is 20° above zero?

ANS. 296,380 for warming; 436,363 + for ventilation.

3. A dwelling-house of average wooden construction measures 200 feet around the outside, and has 3 stories, each 9 feet high. Compute the heat loss by the approximate method when the temperature is 10° below zero.

ANS. 270,000 B. T. U. per hour.

FURNACE HEATING

In construction, a furnace is a large stove with a combustion chamber of ample size over the fire, the whole being inclosed in a casing of sheet iron or brick. The bottom of the casing is provided with a cold-air inlet, and at the top are pipes which connect with registers placed in the various rooms to be heated. Cold, fresh air is brought from out of doors through a pipe or duct called the *cold-air box;* this air enters the space between the casing and the furnace near the bottom, and, in passing over the hot surfaces of the fire-pot and combustion chamber, becomes heated. It then rises through the warm-air pipes at the top of the casing, and is discharged through the registers into the rooms above.

As the warm air is taken from the top of the furnace, cold air flows in through the cold-air box to take its place. The air for heating the rooms does not enter the combustion chamber.

Fig. 5 shows the general arrangement of a furnace with its connecting pipes. The cold-air inlet is seen at the bottom, and the hot-air pipes at the top; these are all provided with dampers for shutting off or regulating the amount of air flowing through them. The feed or fire door is shown at the front, and the ash door beneath it; a *water-pan* is placed inside the casing, and furnishes moisture to the warm air before passing into the rooms; water is either poured into the pan through an opening in the front, provided for this purpose, or is supplied automatically through a pipe.

The fire is regulated by means of a draft slide in the ash door, and a cold-air or regulating damper placed in the smoke-pipe. Clean-out doors are placed at different points in the casing for the removal of ashes and soot. Furnaces are made either of cast iron, or of wrought-iron plates riveted together and provided with brick-lined firepots.

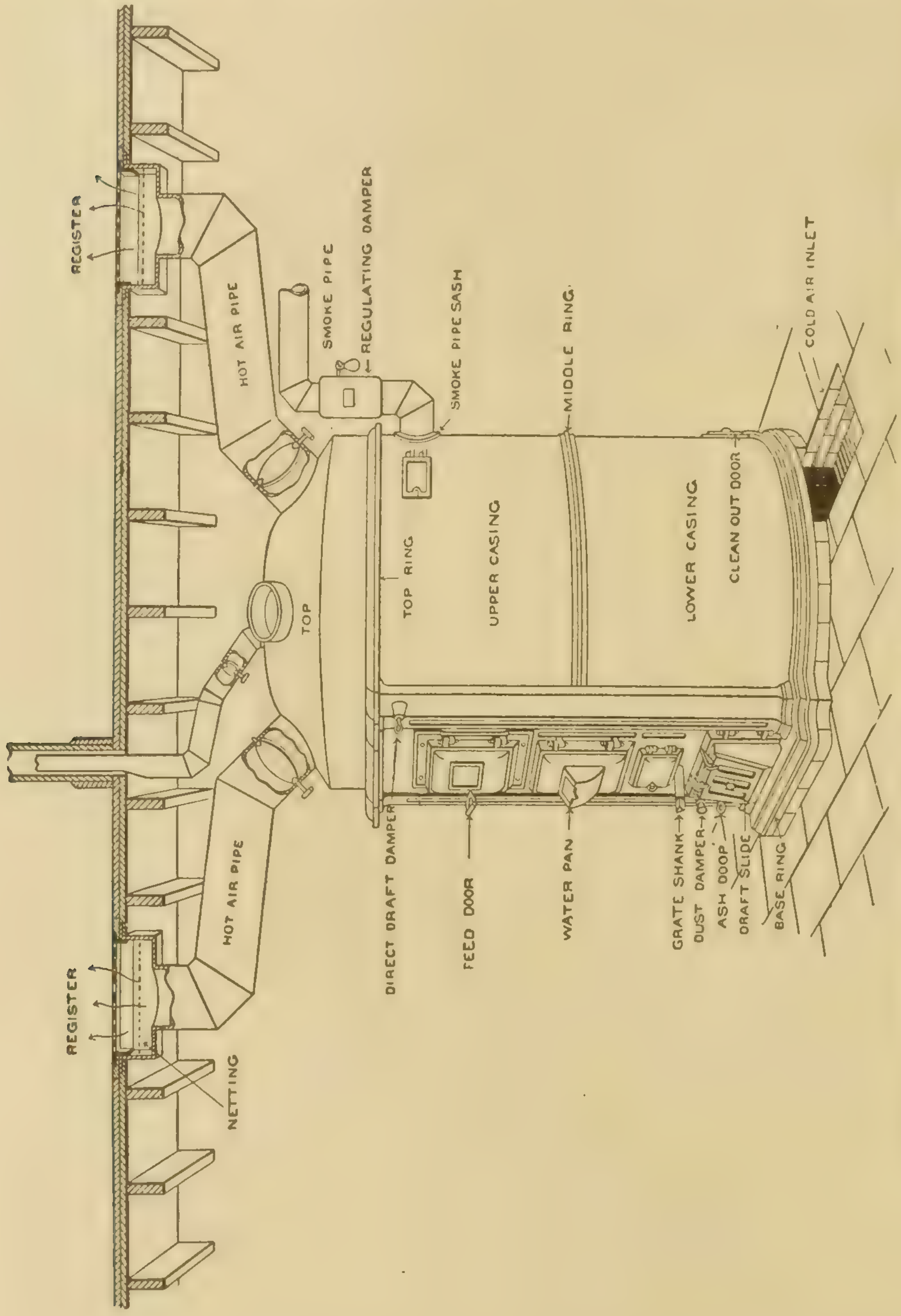


Fig. 5. General Arrangement of Details of a Hot-Air Furnace, with Connecting Pipes.

Types of Furnaces. Furnaces may be divided into two general types known as *direct-draft* and *indirect-draft.* Fig. 6 shows a common form of *direct-draft* furnace with a brick setting; the better class have a radiator, generally placed at the top, through which the gases pass before reaching the smoke-pipe. They have but one damper, usually combined with a cold-air check. Many of the cheaper direct-draft furnaces have no radiator at all, the gases passing directly into the smoke-pipe and carrying away much heat that should be utilized.

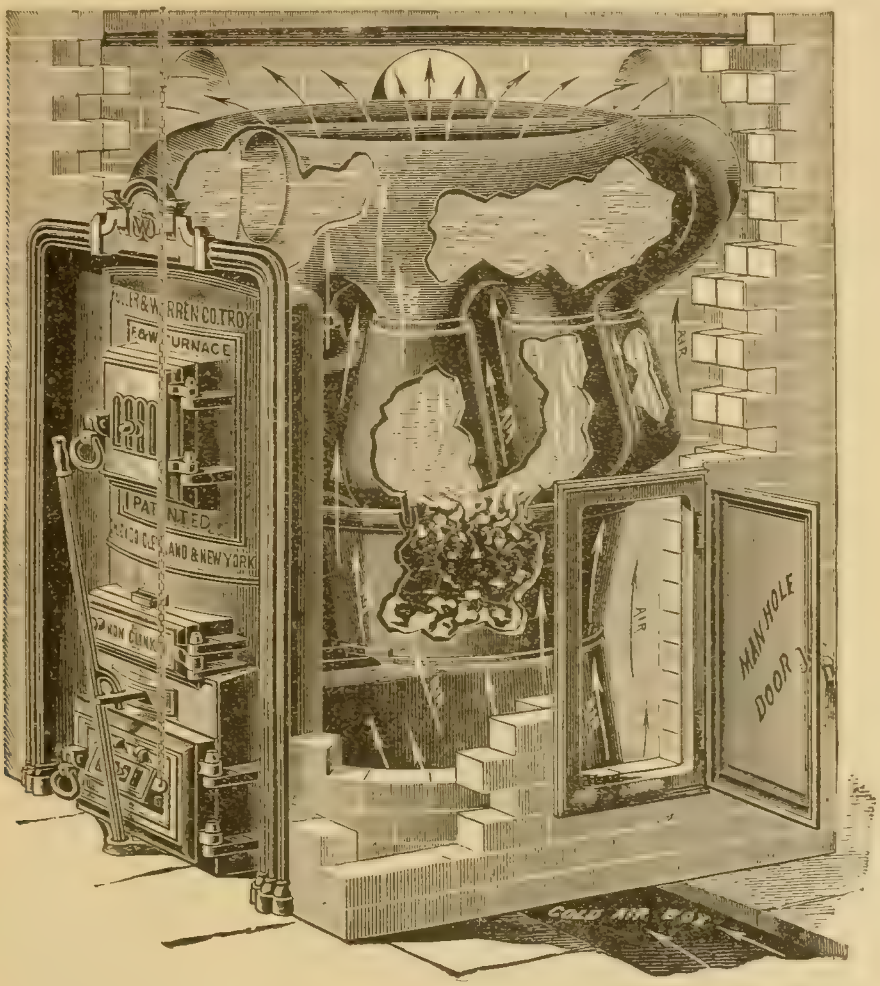


Fig. 6. A Common Type of Direct-Draft Furnace in Brick Setting. Cast-Iron Radiator at Top.

The furnace shown in Fig. 6 is made of cast iron and has a large radiator at the top; the smoke connection is shown at the rear.

Fig. 7 represents another form of direct-draft furnace. In this case the radiator is made of sheet-steel plates riveted together, and the outer casing is of heavy galvanized iron instead of brick.

In the ordinary *indirect-draft* type of furnace (see Fig. 8), the gases pass downward through flues to a radiator located near the base, thence upward through another flue to the smoke-pipe. In addition to the damper in the smoke-pipe, a direct-draft damper is required to give direct connection with the funnel when coal is first put on, to facilitate the escape of gas to the chimney. When the chimney draft

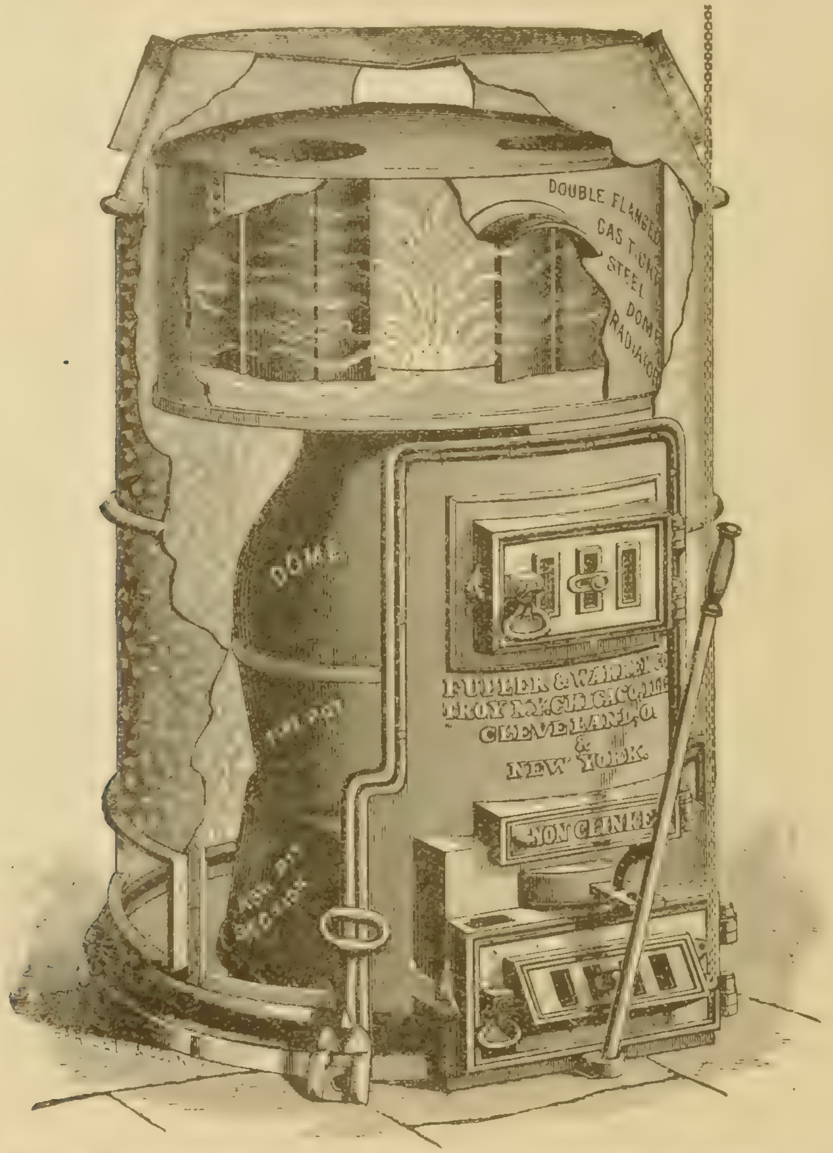

DOUBLE FLANGED GAS TIGHT STEEL DOME RADIATOR
DOME
FULLER & WARREN CO.
TROY N.Y. CHICAGO, ILL.
CLEVELAND, O.
&
NEW YORK.
NON CLINKER

Fig. 7. Direct-Draft Furnace with Galvanized-Iron Casing. Radiator (at top) Made of Riveted Steel Plates.

is weak, trouble from gas is more likely to be experienced with furnaces of this type than with those having a direct draft.

Grates. No part of a furnace is of more importance than the grates. The plain grate rotating about a center pin was for a long time the one most commonly used. These grates were usually provided with a clinker door for removing any refuse too large to pass between the grate bars. The action of such grates tends to leave a cone of ashes in the center of the fire causing it to burn more freely around the edges. A better form of grate is the revolving triangular pattern, which is now used in many of the leading furnaces. It consists of a series of triangular bars having teeth. The bars are connected by gears, and are turned by means of a detachable lever. If properly used, this grate will cut a slice of ashes and clinkers from under the entire fire with little, if any loss of unconsumed coal.

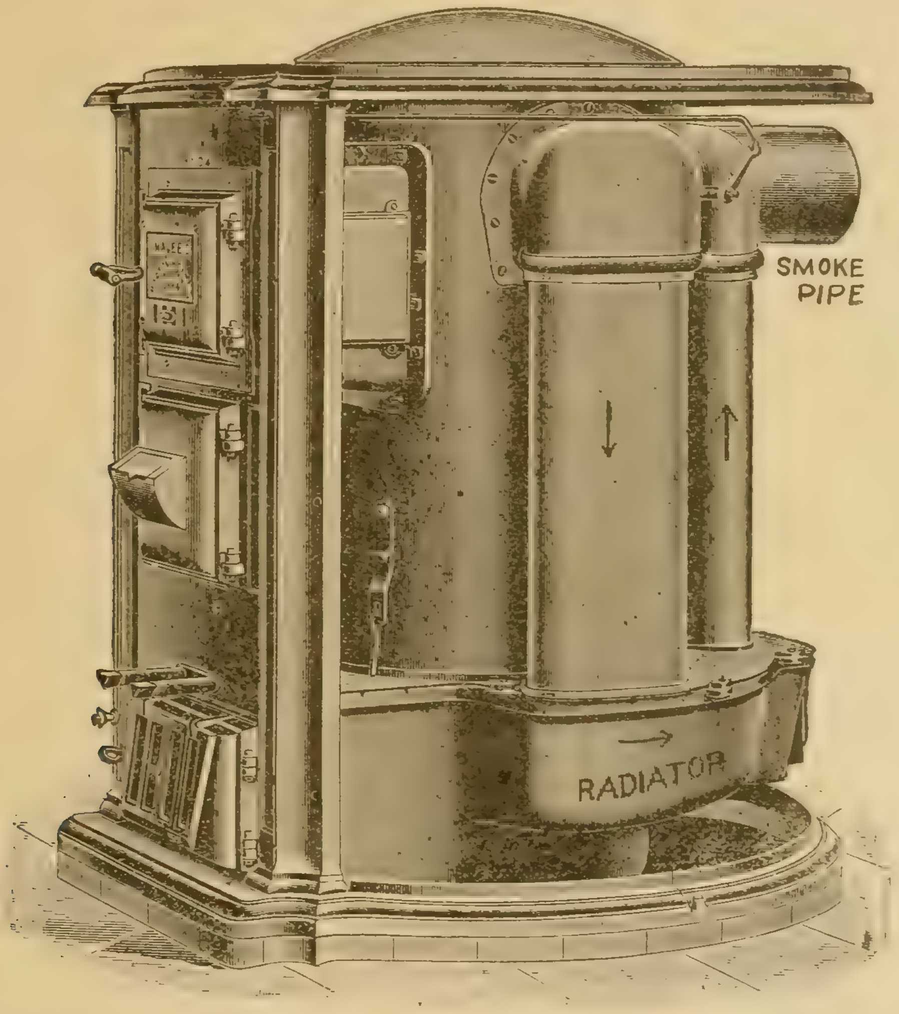


Fig. 8. Indirect-Draft Type of Furnace. Gases Pass Downward to Radiator at Bottom, Thence Upward to Smoke-Pipe.

The Firepot. Firepots are generally made of cast iron or of steel plate lined with firebrick. The depth ranges from about 12 to 18 inches. In cast-iron furnaces of the better class, the firepot is made very heavy, to insure durability and to render it less likely to become red-hot. The firepot is sometimes made in two pieces, to reduce the liability to cracking. The heating surface is sometimes increased by corrugations, pins, or ribs.

A firebrick lining is necessary in a wrought-iron or steel furnace to protect the thin shell from the intense heat of the fire. Since brick-lined firepots are much less effective than cast-iron in transmitting heat, such furnaces depend to a great extent for their efficiency on the heating surface in the dome and radiator; and this, as a rule, is much greater than in those of cast iron.

Cast-iron furnaces have the advantage when coal is first put on (and the drop flues and radiator are cut out by the direct damper) of still giving off heat from the firepot, while in the case of brick linings very little heat is given off in this way, and the rooms are likely to become somewhat cooled before the fresh coal becomes thoroughly ignited.

Combustion Chamber. The body of the furnace above the firepot, commonly called the *dome* or *feed section*, provides a combustion chamber. This chamber should be of sufficient size to permit the gases to become thoroughly mixed with the air passing up through the fire or entering through openings provided for the purpose in the feed door. In a well-designed furnace, this space should be somewhat larger than the firepot.

Radiator. The radiator, so called, with which all furnaces of the better class are provided, acts as a sort of reservoir in which the gases are kept in contact with the air passing over the furnace until they have parted with a considerable portion of their heat. Radiators are built of cast iron, of steel plate, or of a combination of the two. The former is more durable and can be made with fewer joints, but owing to the difficulty of casting radiators of large size, steel plate is commonly used for the sides.

The effectiveness of a radiator depends on its form, its heating surface, and the difference between the temperature of the gases and the surrounding air. Owing to the accumulation of soot, the bottom surface becomes practically worthless after the furnace has been in use a short time; surfaces, to be effective, must therefore be self-cleaning.

If the radiator is placed near the bottom of the furnace the gases are surrounded by air at the lowest temperature, which renders the radiator more effective for a given size than if placed near the top and surrounded by warm air. On the other hand, the cold air has a tendency to condense the gases, and the acids thus formed are likely to corrode the iron.

Heating Surface. The different heating surfaces may be described as follows: Firepot surface; surfaces acted upon by direct rays of heat from the fire, such as the dome or combustion chamber; gas- or smoke-heated surfaces, such as flues or radiators; and extended surfaces, such as pins or ribs. Surfaces unlike in character and location, vary greatly in heating power, so that, in making comparisons of different furnaces, we must know the kind, form, and location of the heating surfaces, as well as the area.

In some furnaces having an unusually large amount of surface, it will be found on inspection that a large part would soon become practically useless from the accumulation of soot. In others a large portion of the surface is lined with firebrick, or is so situated that the air-currents are not likely to strike it.

The ratio of grate to heating surface varies somewhat according to the size of furnace. It may be taken as 1 to 25 in the smaller sizes, and 1 to 15 in the larger.

Efficiency. One of the first items to be determined in estimating the heating capacity of a furnace, is its efficiency—that is, the proportion of the heat in the coal that may be utilized for warming. The efficiency depends chiefly on the area of the heating surface as compared with the grate, on its character and arrangement, and on the rate of combustion. The usual proportions between grate and heating surface have been stated. The rate of combustion required to maintain a temperature of 70° in the house, depends, of course, on the outside temperature. In very cold weather a rate of 4 to 5 pounds of coal per square foot of grate per hour must be maintained.

One pound of good anthracite coal will give off about 13,000 B. T. U., and a good furnace should utilize 70 per cent of this heat. The efficiency of an ordinary furnace is often much less, sometimes as low as 50 per cent.

In estimating the required size of a first-class furnace with good chimney draft, we may safely count upon a maximum combustion of 5 pounds of coal per square foot of grate per hour, and may assume that 8,000 B. T. U. will be utilized for warming purposes from each pound burned. This quantity corresponds to an efficiency of 60 per cent.

Heating Capacity. Having determined the heat loss from a building by the methods previously given, it is a simple matter to compute the size of grate necessary to burn a sufficient quantity of coal to furnish the amount of heat required for warming.

In computing the size of furnace, it is customary to consider the whole house as a single room, with four outside walls and a cold attic. The heat losses by conduction and leakage are computed, and increased 10 per cent for the cold attic, and 16 per cent for exposure. The heat delivered to the various rooms may be considered as being made up of two parts—*first*, that required to warm the outside air up to 70° (the temperature of the rooms); and *second*, the quantity which must be added to this to offset the loss by conduction and leakage. Air is usually delivered through the registers at a temperature of 120°, with zero conditions outside, in the best class of residence work; so that $\frac{70}{120}$ of the heat given to the entering air may be considered as making up the first part, mentioned above, leaving $\frac{50}{120}$ available for purely heating purposes. From this it is evident that the heat supplied to the entering air must be equal to $1 \div \frac{50}{120} = 2.4$ times that required to offset the loss by conduction and leakage.

Example. The loss through the walls and windows of a building is found to be 80,000 B. T. U. per hour in zero weather. What will be the size of furnace required to maintain an inside temperature of 70 degrees?

From the above, we have the total heat required, equal to $80{,}000 \times 2.4 = 192{,}000$ B. T. U. per hour. If we assume that 8,000 B. T. U. are utilized per pound of coal, then $192{,}000 \div 8{,}000 = 24$ pounds of coal required per hour; and if 5 pounds can be burned on each square foot of grate per hour, then $\frac{24}{5} = 4.8$ square feet required. A grate 30 inches in diameter has an area of 4.9 square feet, and is the size we should use.

When the outside temperature is taken as 10° below zero, multiply by 2.6 instead of 2.4; and multiply by 2.8 for 20° below.

Table VII will be found useful in determining the diameter of firepot required.

TABLE VII

Firepot Dimensions

Average Diameter of Grate, in Inches	Area in Square Feet
18	1.77
20	2.18
22	2.64
24	3.14
26	3.69
28	4.27
30	4.91
32	5.58

EXAMPLES FOR PRACTICE

1. A brick apartment house is 20 feet wide, and has 4 stories, each being 10 feet in height. The house is one of a block, and is exposed only at the front and rear. The walls are 16 inches thick, and the block is so sheltered that no correction need be made for exposure. Single windows make up $\frac{1}{8}$ the total exposed surface. Figure for cold attic but warm basement. What area of grate surface will be required for a furnace to keep the house at a temperature of 70° when it is 10° below zero outside? Ans. 3.5 square feet.

2. A house having a furnace with a firepot 30 inches in diameter, is not sufficiently warmed, and it is decided to add a second furnace to be used in connection with the one already in. The heat loss from the building is found by computation to be 133,600 B. T. U. per hour, in zero weather. What diameter of firepot will be required for the extra furnace? Ans. 24 inches.

Location of Furnace. A furnace should be so placed that the warm-air pipes will be of nearly the same length. The air travels most readily through pipes leading toward the sheltered side of the house and to the upper rooms. Therefore pipes leading toward the north or west, or to rooms on the first floor, should be favored in regard to length and size. The furnace should be placed somewhat to the north or west of the center of the house, or toward the points of compass from which the prevailing winds blow.

Smoke-Pipes. Furnace smoke-pipes range in size from about 6 inches in the smaller sizes to 8 or 9 inches in the larger ones. They are generally made of galvanized iron of No. 24 gauge or heavier. The pipe should be carried to the chimney as directly as possible, avoiding bends which increase the resistance and diminish the draft. Where a smoke-pipe passes through a partition, it should be protected by a soapstone or double-perforated metal collar having a diameter at least 8 inches greater than that of the pipe. The top of the smoke-pipe should not be placed within 8 inches of unprotected beams, nor less than 6 inches under beams protected by asbestos or plaster with a metal shield beneath. A collar to make tight connection with the chimney should be riveted to the pipe about 5 inches from the end, to prevent the pipe being pushed too far into the flue. Where the pipe is of unusual length, it is well to cover it to prevent loss of heat and the condensation of smoke.

Chimney Flues. Chimney flues, if built of brick, should have walls 8 inches in thickness, unless terra-cotta linings are used, when only 4 inches of brickwork is required. Except in small houses where an 8 by 8-inch flue may be used, the nominal size of the smoke flue should be at least 8 by 12-inches, to allow for contractions or offsets. A clean-out door should be placed at the bottom of the flue, for removing ashes and soot. A square flue cannot be reckoned at its full area, as the corners are of little value. To avoid down drafts, the top of the chimney must be carried above the highest point of the roof unless provided with a suitable hood or top.

Cold-Air Box. The cold-air box should be large enough to supply a volume of air sufficient to fill all the hot-air pipes at the same time. If the supply is too small, the distribution is sure to be unequal, and the cellar will become overheated from lack of air to carry away the heat generated.

If a box is made too small, or is throttled down so that the volume of air entering the furnace is not large enough to fill all the pipes, it will be found that those leading to the less exposed side of the house or to the upper rooms will take the entire supply, and that additional air to supply the deficiency will be drawn down through registers in rooms less favorably situated. It is common practice to make the area of the cold-air box three-fourths the combined area of the hot-air pipes. The inlet should be placed where the prevailing cold winds will blow into it; this is commonly on the north or west side of the house. If it is placed on the side away from the wind, warm air from the furnace is likely to be drawn out through the cold-air box.

Whatever may be the location of the entrance to the cold-air box, changes in the direction of the wind may take place which will bring the inlet on the wrong side of the house. To prevent the possibility of such changes affecting the action of the furnace, the cold-air box is sometimes extended through the house and left open at both ends, with check-dampers arranged to prevent back-drafts. These checks should be placed some distance from the entrance, to prevent their becoming clogged with snow or sleet.

The cold-air box is generally made of matched boards; but galvanized iron is much better; it costs more than wood, but is well worth the extra expense on account of tightness, which keeps the dust and ashes from being drawn into the furnace casing to be discharged through the registers into the rooms above.

The cold-air inlet should be covered with galvanized wire netting with a mesh of at least three-eighths of an inch. The frame to which it is attached should not be smaller than the inside dimensions of the cold-air box. A door to admit air from the cellar to the cold-air box is generally provided. As a rule, air should be taken from this source, only when the house is temporarily unoccupied or during high winds.

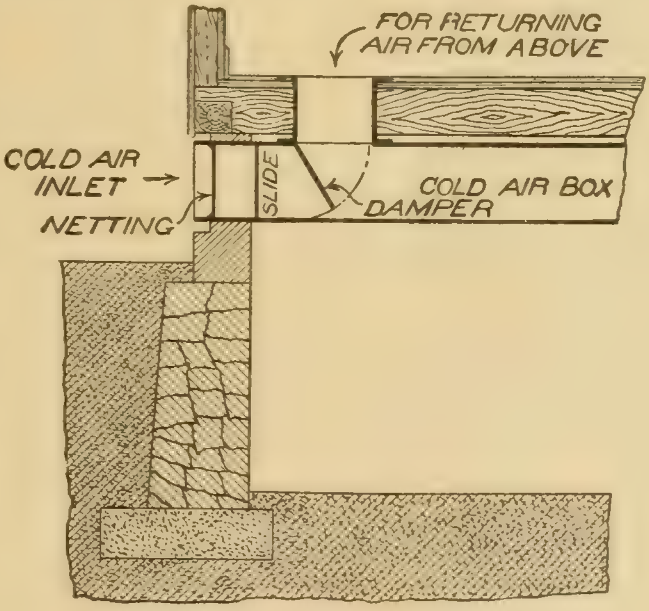


Fig 9. Common Method of Connecting Return Duct to Cold-Air Box.

Return Duct. In some cases it is desirable to return air to the furnace from the rooms above, to be reheated. Ducts for this purpose are common in places where the winter temperature is frequently below zero. Return ducts when used, should be in addition to the regular cold-air box. Fig. 9 shows a common method of making the connection between the two. By proper adjustment of the swinging damper, the air can be taken either from out of doors or through the register from the room above. The return register is often placed in the hallway of a house, so that it will take the cold air which rushes in when the door is opened and also that which may leak in around it while closed. Check-valves or flaps of light gossamer or woolen cloth should be placed between the cold-air box and the registers to prevent back-drafts during winds.

The return duct should not be used too freely at the expense of outdoor air, and its use is not recommended except during the night when air is admitted to the sleeping rooms through open windows.

Warm-Air Pipes. The required size of the warm-air pipe to any given room, depends on the heat loss from the room and on the volume of warm air required to offset this loss. Each cubic foot of air warmed from zero to 120 degrees brings into a room 2.2 B. T. U. We have already seen that in zero weather, with the air entering the registers at 120 degrees, only $\frac{50}{120}$ of the heat contained in the air is available for offsetting the losses by radiation and conduction, so that only $2.2 \times \frac{50}{120} = .9$ B. T. U. in each cubic foot of entering air can be utilized for warming purposes. Therefore, if we divide the computed heat loss in B. T. U. from a room, by .9, it will give the number of cubic feet of air at 120 degrees necessary to warm the room in zero weather.

As the outside temperature becomes colder, the quantity of heat brought in per cubic foot of air increases; but the proportion available for warming purposes becomes less at nearly the same rate, so

TABLE VIII

Warm-Air Pipe Dimensions

Diameter of Pipe, in Inches	Area in Square Inches	Area in Square Feet
6	28	.196
7	38	.267
8	50	.349
9	64	.442
10	79	.545
11	95	.660
12	113	.785
13	133	.922
14	154	1.07
15	177	1.23
16	201	1.40

that for all practical purposes we may use the figure .9 for all usual conditions. In calculating the size of pipe required, we may assume maximum velocities of 260 and 380 feet per minute for rooms on the first and second floors respectively. Knowing the number of cubic feet of air per minute to be delivered, we can divide it by the velocity, which will give us the required area of the pipe in square feet.

Round pipes of tin or galvanized iron are used for this purpose. Table VIII will be found useful in determining the required diameters of pipe in inches.

Example. The heat loss from a room on the second floor is 18,000 B. T. U. per hour. What diameter of warm-air pipe will be required?

18,000 ÷ .9 = 20,000 = cubic feet of air required per hour. 20,000 ÷ 60 = 333 per minute. Assuming a velocity of 380 feet per minute, we have 333 ÷ 380 = .87 square foot, which is the area of pipe required. Referring to Table VIII, we find this comes between a 12-inch and a 13-inch pipe, and the larger size would probably be chosen.

EXAMPLES FOR PRACTICE

1. A first-floor room has a computed loss of 27,000 B. T. U. per hour when it is 10° below zero. The air for warming is to enter through two pipes of equal size, and at a temperature of 120 degrees. What will be the required diameter of the pipes?

Ans. 14 inches.

2. If in the above example the room had been on the second floor, and the air was to be delivered through a single pipe, what diameter would be required?

Ans. 16 inches.

Since long horizontal runs of pipe increase the resistance and loss of heat, they should not in general be over 12 or 14 feet in length. This applies especially to pipes leading to rooms on the first floor, or to those on the cold side of the house. Pipes of excessive length should be increased in size because of the added resistance.

Figs. 10 and 11 show common methods of running the pipes in the basement. The first gives the best results, and should be used where the basement is of sufficient height to allow it. A damper should be placed in each pipe near the furnace, for regulating the flow of air to the different rooms, or for shutting it off entirely when desired.

While round pipe risers give the best results, it is not always possible to provide a sufficient space for them, and flat or oval pipes are substituted. When vertical pipes must be placed in single partitions, much better results will be obtained if the studding can be made 5 or 6 inches deep instead of 4 as is usually done. Flues should never in any case be made less than 3½ inches in depth. Each room should be heated by a separate pipe. In some cases, however, it is allowable to run a single riser to heat two unimportant rooms on an upper floor. A clear space of at least ½ inch should be left between the risers and studs, and the latter should be carefully tinned, and the

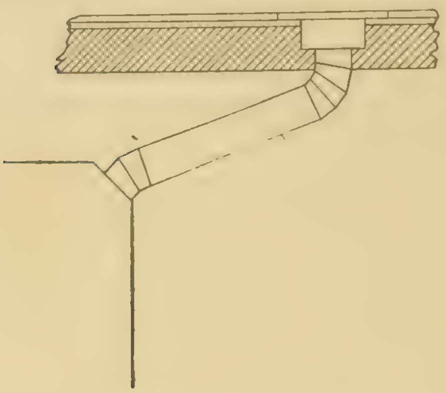


Fig. 10.

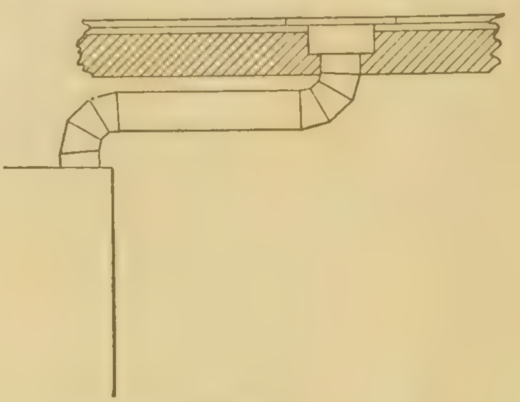
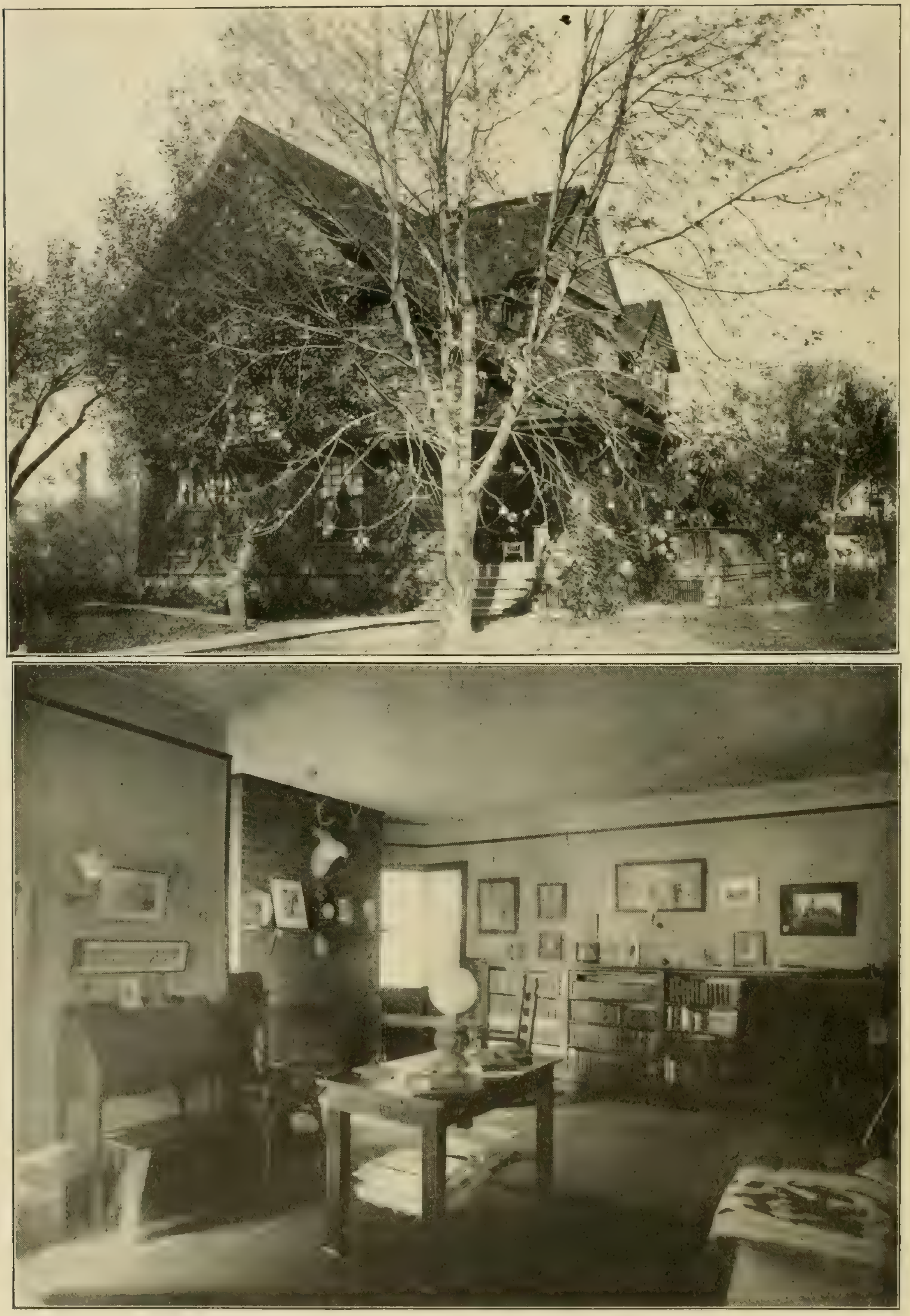


Fig. 11.

Common Methods of Running Hot-Air Pipes in Basement. Method Shown in Fig. 10 is Preferable where Feasible.

TABLE IX
Dimensions of Oval Pipes

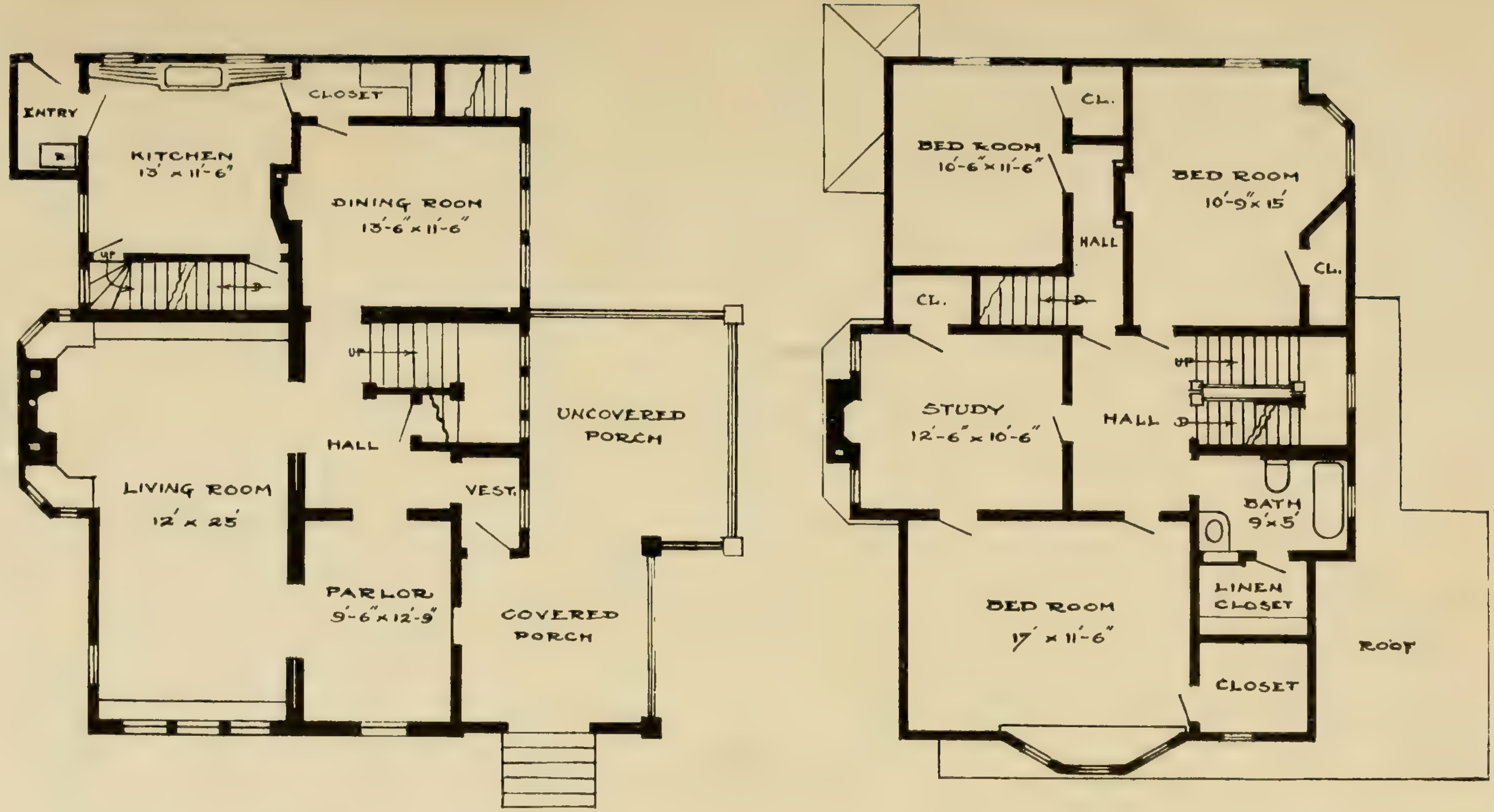
Dimension of Pipe	Area in Square Inches
6 ovaled to 5 in.	27
7 “ “ 4 “	31
7 “ “ 3½ “	29
7 “ “ 6 “	38
8 “ “ 5 “	43
9 “ “ 4 “	45
9 “ “ 6 “	57
9 “ “ 5 “	51
10 “ “ 3½ “	46
11 “ “ 4 “	58
12 “ “ 3½ “	55
10 “ “ 6 “	67
11 “ “ 5 “	67
14 “ “ 4 “	76
15 “ “ 3½ “	73
12 “ “ 6 “	85
12 “ “ 5 “	75
19 “ “ 4 “	96
20 “ “ 3½ “	100



EXTERIOR VIEW AND COMBINED LIBRARY AND LIVING ROOM IN HOUSE AT URBANA, ILL.

White & Temple, Architects, University of Illinois.

Plans Shown on Opposite Page.



FIRST FLOOR PLAN

SECOND FLOOR PLAN

FIRST AND SECOND FLOOR PLANS OF HOUSE IN URBANA, ILL.
White & Temple, Architects, University of Illinois.
For Exterior and Interior Views, See Opposite Page.

space between them on both sides covered with tin, asbestos, or wire lath.

Table IX gives the capacity of oval pipes. A 6-inch pipe ovaled to 5 means that a 6-inch pipe has been flattened out to a thickness of 5 inches, and column 2 gives the resulting area.

Having determined the size of round pipe required, an equivalent oval pipe can be selected from the table to suit the space available.

Registers. The registers which control the supply of warm air to the rooms, generally have a net area equal to two-thirds of their gross area. The net area should be from 10 to 20 per cent greater than the area of the pipe connected with it. It is common practice to use registers having the short dimensions equal to, and the long dimensions about one-half greater than, the diameter of the pipe. This would give standard sizes for different diameters of pipe, as listed in Table X.

TABLE X

Sizes of Registers for Different Sizes of Pipes

DIAMETER OF PIPE	SIZE OF REGISTER
6 in.	6 × 10 in.
7 "	7 × 10 "
8 "	8 × 12 "
9 "	9 × 14 "
10 "	10 × 15 "
11 "	11 × 16 "
12 "	12 × 17 "
13 "	14 × 20 "
14 "	14 × 22 "
15 "	15 × 22 "
16 "	16 × 24 "

Combination Systems. A combination system for heating by hot air and hot water consists of an ordinary furnace with some form of surface for heating water, placed either in contact with the fire or suspended above it. Fig. 12 shows a common arrangement where part of the heating surface forms a portion of the lining to the firepot and the remainder is above the fire.

Care must be taken to proportion properly the work to be done by the air and the water; else one will operate at the expense of the other. One square foot of heating surface in contact with the fire is capable of supplying from 40 to 50 square feet of radiating surface, and one square foot suspended over the fire will supply from 15 to 25 square feet of radiation.

The value or efficiency of the heating surface varies so widely in different makes that it is best to state the required conditions to the manufacturers and have them proportion the surfaces as their experience has found best for their particular type of furnace.

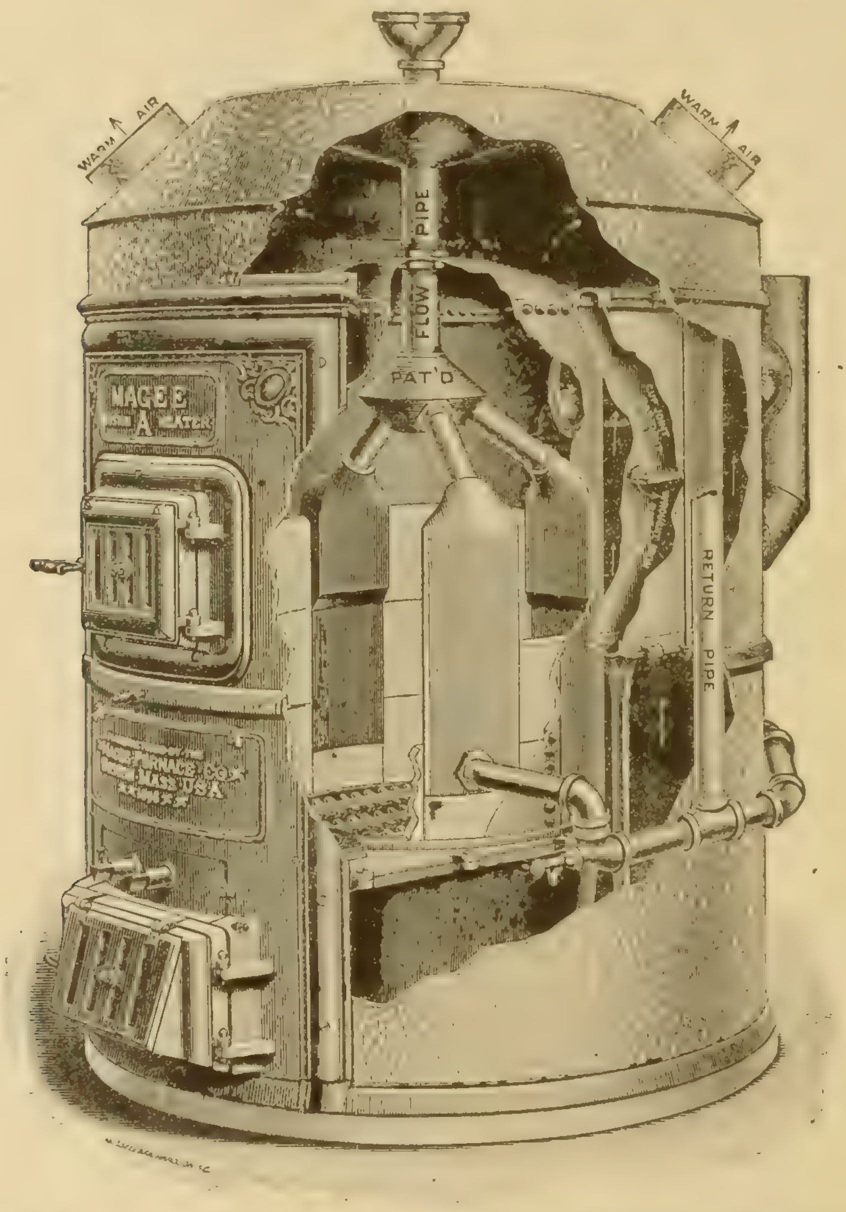


Fig. 12. Combination Furnace, for Heating by Both Hot Air and Hot Water.

Care and Management of Furnaces. The following general rules apply to the management of all hard coal furnaces.

The fire should be thoroughly shaken once or twice daily in cold weather. It is well to keep the firepot heaping full at all times. In this way a more even temperature may be maintained, less attention is required, and no more coal is burned than when the pot is only partly filled. In mild weather the mistake is frequently made of carrying a thin fire, which requires frequent attention and is likely to die out. Instead, to diminish the temperature in the house, keep the firepot full and allow ashes to accumulate on the grate (not under it) by shaking less frequently or less vigorously. The ashes will hold the heat and render it an easy matter to maintain and control the fire. When feeding coal on a low fire, open the drafts and neither rake nor shake the fire till the fresh coal becomes ignited. The air supply to the fire is of the greatest importance. An insufficient amount results in incomplete combustion and a great loss of heat. To secure proper combustion, the fire should be controlled principally by means of the ash-pit through the ash-pit door or slide.

The smoke-pipe damper should be opened only enough to carry off the gas or smoke and to give the necessary draft. The openings in the feed door act as a check on the fire, and should be kept closed during cold weather, except just after firing, when with a good draft they may be partly opened to increase the air-supply and promote the proper combustion of the gases.

Keep the ash-pit clear to avoid warping or melting the grate. The cold air box should be kept wide open except during winds or when the fire is low. At such times it may be partly, but never completely closed. Too much stress cannot be laid on the importance of a sufficient air-supply to the furnace. It costs little if any more to maintain a comfortable temperature in the house night and day than to allow the rooms to become so cold during the night that the fire must be forced in the morning to warm them up to a comfortable temperature.

In case the warm air fails at times to reach certain rooms, it may be forced into them by temporarily closing the registers in other rooms. The current once established will generally continue after the other registers have been opened.

It is best to burn as hard coal as the draft will warrant. Egg size is better than larger coal, since for a given weight small lumps expose more surface and ignite more quickly than larger ones. The furnace and smoke-pipe should be thoroughly cleaned once a year.

This should be done just after the fire has been allowed to go out in the spring.

STEAM BOILERS

Types. The boilers used for heating are the same as have already been described for power work. In addition there is the cast-iron sectional boiler, used almost exclusively for dwelling-houses.

Tubular Boilers. Tubular boilers are largely used for heating purposes, and are adapted to all classes of buildings except dwelling-houses and the special cases mentioned later, for which sectional boilers are preferable. A *boiler horse-power* has been defined as the evaporation of $34\frac{1}{2}$ pounds of water from and at a temperature of 212 degrees, and in doing this 33,317 B. T. U. are absorbed, which are again given out when the steam is condensed in the radiators. Hence to find the boiler H. P. required for warming any given building, we have only to compute the heat loss per hour by the methods already given, and divide the result by 33,330. It is more common to divide by the number 33,000, which gives a slightly larger boiler and is on the side of safety.

The commercial horse-power of a well-designed boiler is based upon its heating surface; and for the best economy in heating work, it should be so proportioned as to have about 1 square foot heating of surface for each 2 pounds of water to be evaporated from and at 212 degrees F. This gives $34.5 \div 2$ 17.2 square feet of heating surface per horse-power, which is generally taken as 15 in practice. Makers of tubular boilers commonly rate them on a basis of 12 square feet of heating surface per horse-power. This is a safe figure under the conditions of power work, where skilled firemen are employed and where more care is taken to keep the heating surfaces free from soot and ashes. For heating plants, however, it is better to rate the boilers upon 15 square feet per horse-power as stated above.

There is some difference of opinion as to the proper method of computing the heating surface of tubular boilers. In general, all surface is taken which is exposed to the hot gases on one side and to the water on the other. A safe rule, and the one by which Table XII is computed, is to take $\frac{1}{2}$ the area of the shell, $\frac{2}{3}$ of the rear head, less the tube area, and the interior surface of all the tubes.

The required amount of grate area, and the proper ratio of heating surface to grate area, vary a good deal, depending on the character of the fuel and on the chimney draft. By assuming the probable rates of combustion and evaporation, we may compute the required grate area for any boiler from the formula:

$$S = \frac{H.P. \times 34.5}{E \times C},$$

In which

S = Total grate area, in square feet;
E = Pounds of water evaporated per pound of coal;
C = Pounds of coal burned per square foot of grate per hour.

Table XI gives the approximate grate area per H. P. for different rates of evaporation and combustion as computed by the above equation.

TABLE XI

Grate Area per Horse-Power for Different Rates of Evaporation and Combustion

Pounds of Steam per Pound of Coal	Pounds of Coal Burned per Square Foot of Grate per Hour		
	8 lbs.	10 lbs.	12 lbs.
	Square Feet of Grate Surface per Horse-Power		
10	.43	.35	.28
9	.48	.38	.32
8	.54	.43	.36
7	.62	.49	.41
6	.72	.58	.48

For example, with an evaporation of 8 pounds of steam per pound of coal, and a combustion of 10 pounds of coal per square foot of grate, .43 of a square foot of grate surface per H. P. would be called for.

The ratio of heating to grate surface in this type of boiler ranges from 30 to 40, and therefore allows under ordinary conditions a combustion of from 8 to 10 pounds of coal per square foot of grate. This is easily obtained with a good chimney draft and careful firing. The larger the boiler, the more important the plant usually, and the greater the care bestowed upon it, so that we may generally count on a higher rate of combustion and a greater efficiency as the size of the boiler increases. Table XII will be found very useful in determining the size of boiler required under different conditions. The grate area is computed for an evaporation of 8 pounds of water per pound

TABLE XII

Diameter of Shell in Inches	Number of Tubes	Diameter of Tubes in Inches	Length of Tubes in Feet	Horse-Power	Size of Grate in Inches	Size of Uptake in Inches	Size of Smoke-pipe in Sq. In
30	28	2½	6	8.5	24 x 36	10 x 14	140
			7	9.9	24 x 36	10 x 14	140
			8	11.2	24 x 36	10 x 14	140
			9	12.6	24 x 42	10 x 14	140
			10	14.0	24 x 42	10 x 14	140
36	34	2½	8	13.6	30 x 36	10 x 16	160
			9	15.3	30 x 42	10 x 18	180
			10	16.9	30 x 42	10 x 18	180
			11	18.6	30 x 48	10 x 20	200
			12	20.9	30 x 48	10 x 20	200
42	34	3	9	18.5	36 x 42	10 x 20	200
			10	20.5	36 x 42	10 x 20	200
			11	22.5	36 x 48	10 x 25	250
			12	24.5	36 x 48	10 x 25	250
			13	26.5	36 x 48	10 x 28	280
			14	28.5	36 x 54	10 x 28	280
48	44	3	10	30.4	42 x 48	10 x 28	280
			11	33.2	42 x 48	10 x 28	280
			12	35.7	42 x 54	10 x 32	320
			13	38.3	42 x 54	10 x 32	320
			14	40.8	42 x 60	10 x 36	360
			15	43.4	42 x 60	10 x 36	360
			16	45.9	42 x 60	10 x 36	360
54	54	3	11	34.6	48 x 54	10 x 38	380
			12	37.7	48 x 54	10 x 38	380
			13	40.8	48 x 54	10 x 38	380
			14	43.9	48 x 54	10 x 38	380
			15	47.0	48 x 60	10 x 40	400
			16	50.1	48 x 60	10 x 40	400
	46	3½	17	53.0	48 x 60	10 x 40	400
60	72	3	12	48.4	54 x 60	12 x 40	460
			13	52.4	54 x 60	12 x 40	460
			14	56.4	54 x 60	12 x 40	460
			15	60.4	54 x 66	12 x 42	500
			16	64.4	54 x 66	12 x 42	500
	64	3½	17	71.4	54 x 72	12 x 48	550
			18	75.6	54 x 72	12 x 48	550
66	90	3	14	70.1	60 x 66	12 x 48	500
			15	75.0	60 x 72	12 x 52	620
			16	80.0	60 x 72	12 x 52	620
	78	3½	17	86.0	60 x 78	12 x 56	670
			18	91.1	60 x 78	12 x 56	670
			19	96.2	60 x 78	12 x 56	670
	62	4	20	93.1	60 x 78	12 x 56	670
72	114	3	14	87.4	66 x 72	12 x 56	670
			15	93.6	66 x 72	12 x 56	670
			16	99.7	66 x 78	12 x 62	740
	98	3½	17	106.4	66 x 78	12 x 62	740
			18	112.6	66 x 84	12 x 66	790
			19	118.8	66 x 84	12 x 66	790
	72	4	20	107.3	66 x 84	12 x 66	790

of coal, which corresponds to an efficiency of about 60 per cent, and is about the average obtained in practice for heating boilers.

The areas of uptake and smoke-pipe are figured on a basis of 1 square foot to 7 square feet of grate surface, and the results given in round numbers. In the smaller sizes the relative size of smoke-pipe is greater. The rate of combustion runs from 6 pounds in the smaller sizes to 11½ in the larger. Boilers of the proportions given in the table, correspond well with those used in actual practice, and may be relied upon to give good results under all ordinary conditions.

Water-tube boilers are often used for heating purposes, but more especially in connection with power plants. The method of computing the required H. P. is the same as for tubular boilers.

Sectional Boilers. Fig. 13 shows a common form of cast-iron boiler. It is made up of slabs or sections, each one of which is connected by nipples with headers at the sides and top. The top header acts as a steam drum, and the lower ones act as mud drums; they also receive the water of condensation from the radiators. The gases from the fire pass backward and forward through flues and are finally taken off at the rear of the boiler.

Another common form of sectional boiler is shown in Fig. 14. It is made up of sections which increase the length like the one just described. These boilers have no drum connecting with the sections; but instead, each section connects with the adjacent one through openings at the top and bottom, as shown.

The ratio of heating to grate surface in boilers of this type ranges from 15 to 25 in the best makes. They are provided with the usual attachments, such as pressure-gauge, water-glass, gauge-cocks, and safety-valve; a low-pressure damper regulator is furnished for operating the draft doors, thus keeping the steam pressure practically constant. A pressure of from 1 to 5 pounds is usually carried on these boilers, depending upon the outside temperature. The usual setting is simply a covering of some kind of non-conducting material like plastic magnesia or asbestos, although some forms are enclosed in light brickwork.

In computing the required size, we may proceed in the same manner as in the case of a furnace. For the best types of house-heating boilers, we may assume a combustion of 5 pounds of coal per square foot of grate per hour, and an average efficiency of 60 per cent, which corresponds to 8,000 B. T. U. per pound of coal, available for useful work.

In the case of direct-steam heating, we have only to supply heat to offset that lost by radiation and conduction; so that the grate area may be found by dividing the computed heat loss per hour by 8,000, which gives the number of pounds of coal; and this in turn, divided by 5, will give the area of grate required. The most efficient rate of combustion will depend somewhat upon the ratio between the grate and heating surface. It has been found by experience that about $\frac{1}{4}$ of a pound of coal per hour for each square foot of heating surface gives the best results; so that, by knowing the ratio of heating surface to grate area for any make of heater, we can easily compute the most efficient rate of combustion, and from it determine the necessary grate area.

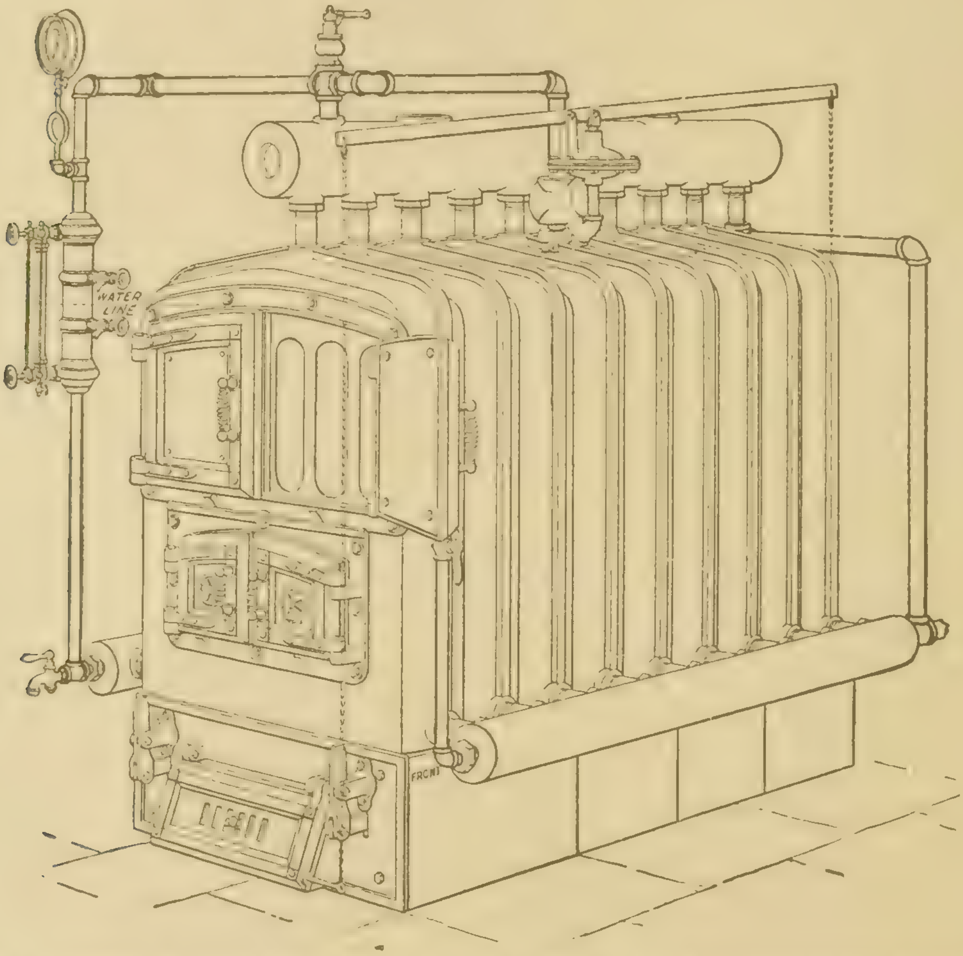


Fig. 13. Common Type of Cast-Iron Sectional Boiler. Note Headers at Sides and Top Acting as Drums.

For example, suppose the heat loss from a building to be 480,000 B. T. U. per hour, and that we wish to use a heater in which the ratio of heating surface to grate area is 24. What will be the most efficient rate of combustion and the required grate area? 480,000 ÷ 8,000 = 60 pounds of coal per hour, and 24 ÷ 4 = 6, which is the best rate of combustion to employ; therefore 60 ÷ 6 = 10, the grate area required.

There are many different designs of cast-iron boilers for low-pressure steam and hot-water heating. In general, boilers having a drum connected by nipples with each section give dryer steam and hold a steadier water-line than the second form, especially when forced above their normal capacity. The steam, in passing through the openings between successive sections in order to reach the outlet, is apt to carry with it more or less water, and to choke the openings, thus producing an uneven pressure in different parts of the boiler.

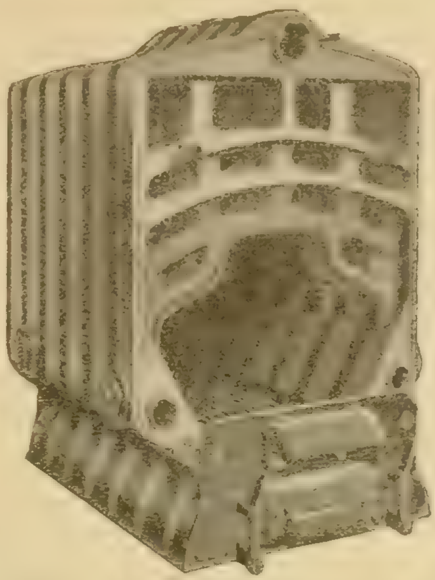


Fig. 14. Another Type of Sectional Boiler. Here there are no drums, the sections being directly connected through openings at top and bottom.
Courtesy of American Radiator Co.

In the case of hot-water boilers this objection disappears.

In order to adapt this type of boiler to steam work, the opening between the sections should be of good size, with an ample steam space above the water-line; and the nozzles for the discharge of steam should be located at frequent intervals.

EXAMPLES FOR PRACTICE

1. The heat loss from a building is 240,000 B. T. U. per hour, and the ratio of heating to grate area in the heater to be used is 20. What will be the required grate area? Ans. 6 sq. ft.

2. The heat loss from a building is 168,000 B. T. U. per hour, and the chimney draft is such that not over 3 pounds of coal per hour can be burned per square foot of grate. What ratio of heating to grate area will be necessary, and what will be the required grate area?
Ans. Ratio, 12. Grate area, 7 sq. ft.

Cast-iron sectional boilers are used for dwelling-houses, small schoolhouses, churches, etc., where low pressures are carried. They are increased in size by adding more slabs or sections. After a certain length is reached, the rear sections become less and less efficient, thus limiting the size and power.

Horse-Power for Ventilation. We already know that one B. T. U. will raise the temperature of 1 cubic foot of air 55 degrees, or it will raise 100 cubic feet $\frac{1}{100}$ of 55 degrees, or $\frac{55}{100}$ of 1 degree; therefore, to raise 100 cubic feet 1 degree, it will take $1 \div \frac{55}{100}$, or $\frac{100}{55}$ B. T. U.; and to raise 100 cubic feet through 100 degrees, it will take $\frac{100}{55} \times 100$ B. T. U. In other words, the B. T. U. required to raise any given volume of air through any number of degrees in temperature, is equal to

$$\frac{\text{Volume of air in cubic ft.} \times \text{Degrees raised}}{55}$$

Example. How many B. T. U. are required to raise 100,000 cubic feet of air 70 degrees?

$$\frac{100{,}000 \times 70}{55} = 127{,}272 +$$

To compute the H. P. required for the ventilation of a building, we multiply the total air-supply, in cubic feet per hour, by the number of degrees through which it is to be raised, and divide the result by 55. This gives the B. T. U. per hour, which, divided by 33,000, will give the H. P. required. In using this rule, always take the air-supply in cubic feet per *hour*.

EXAMPLES FOR PRACTICE

1. The heat loss from a building is 1,650,000 B. T. U. per hour. There is to be an air-supply of 1,500,000 cubic feet per hour, raised through 70 degrees. What is the total boiler H. P. required?

Ans. 108.

2. A high school has 10 classrooms, each occupied by 50 pupils. Air is to be delivered to the rooms at a temperature of 70 degrees. What will be the total H. P. required to heat and ventilate the building when it is 10 degrees below zero, if the heat loss through walls and windows is 1,320,000 B. T. U. per hour? Ans. 106+.

DIRECT-STEAM HEATING

A system of direct-steam heating consists (1) of a furnace and boiler for the combustion of fuel and the generation of steam; (2) a system of pipes for conveying the steam to the radiators and for returning the water of condensation to the boiler; and (3) radiators or coils placed in the rooms for diffusing the heat.

Various types of boilers are used, depending upon the size and kind of building to be warmed. Some form of cast-iron sectional boiler is commonly used for dwelling-houses, while the tubular or water-tube boiler is more usually employed in larger buildings. Where the boiler is used for heating purposes only, a low steam-pressure of from 2 to 10 pounds is carried, and the condensation flows back by gravity to the boiler, which is placed below the lowest radiator. When, for any reason, a higher pressure is required, the steam for the heating system is made to pass through a reducing valve, and the condensation is returned to the boiler by means of a pump or return trap.

Types of Radiating Surface. The radiation used in direct-steam heating is made up of cast-iron radiators of various forms, pipe radiators, and circulation coils.

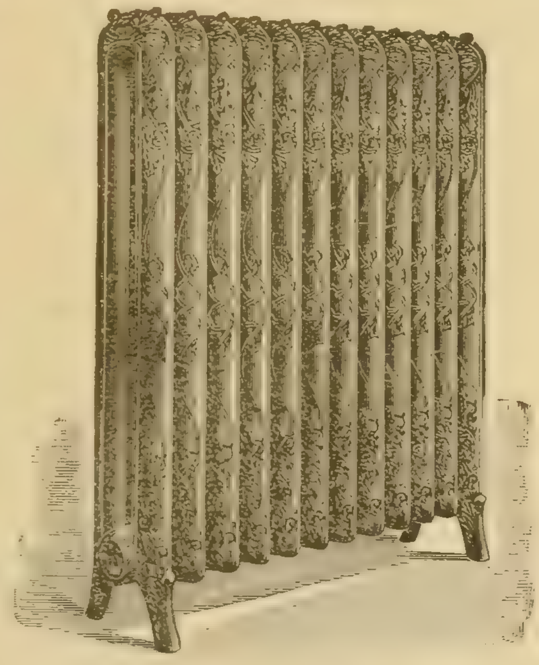


Fig. 15. Common Type of Cast-Iron Sectional Radiator.

Cast-Iron Radiators. The general form of a cast-iron sectional radiator is shown in Fig. 15. Radiators of this type are made up of sections, the number depending upon the amount of heating surface required. Fig. 16 shows an intermediate section of a radiator of this type. It is simply a loop with inlet and outlet at the bottom. The end sections are the same, except that they have legs, as shown in Fig. 17. These sections are connected at the bottom by special nipples, so that steam entering at the end fills the bottom of the radiator, and, being lighter than the air, rises through the loops and forces the air downward and toward the farther end, where it is discharged through an air-valve placed about midway of the last section. There are many different designs varying in height and width, to suit all conditions. The wall pattern shown in Fig. 18 is very convenient when it is desired to place the radiator above the floor, as in bathrooms, etc.; it is also a convenient form to place under the windows of halls and churches to counteract the effect of cold down drafts. It is adapted to nearly every place where the ordinary direct radiator can be used, and may be connected up in different ways to meet the various requirements.

A low and moderately shallow radiator, with ample space for the circulation of air between the sections, is more efficient than a deep radiator with the sections closely packed together. One- and two-column radiators, so called, are preferable to three- and four-column, when there is sufficient space to use them.

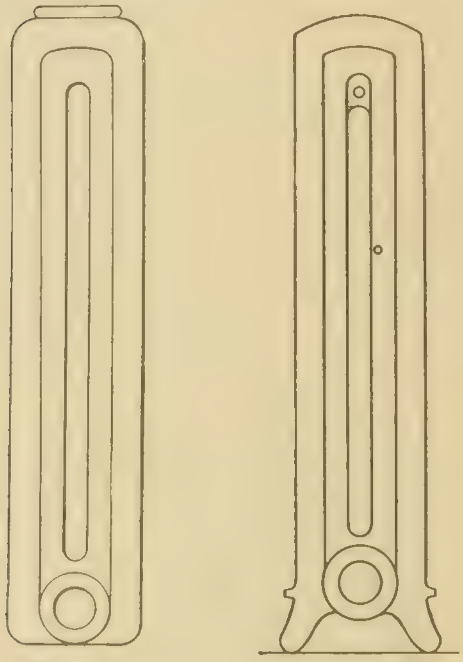


Fig. 16. Fig. 17.

Intermediate and End Sections of Radiator Shown in Fig. 15. The end sections (at right) have legs.

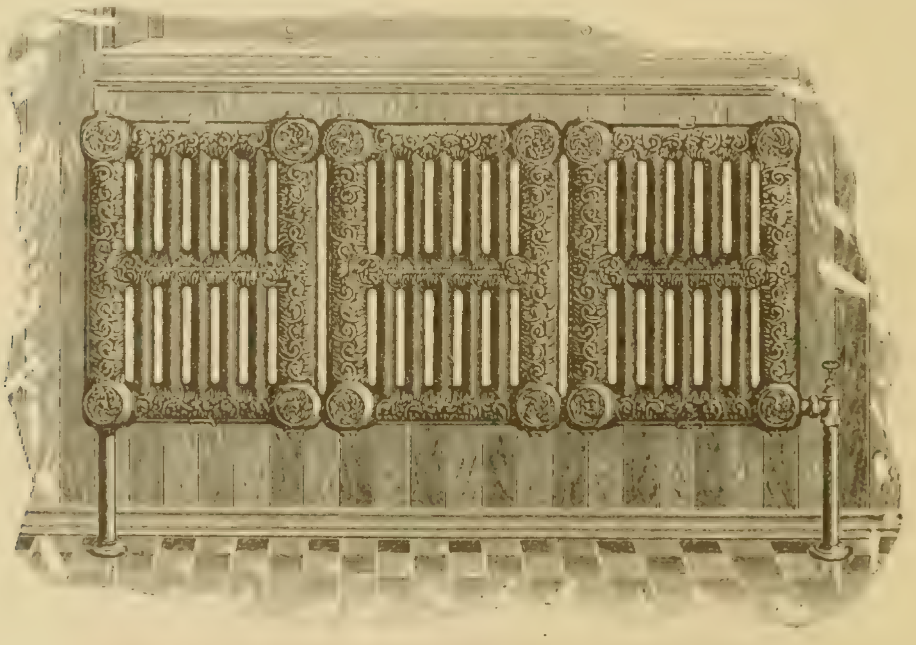


Fig. 18. Cast-Iron Sectional Radiator of Wall Pattern.

The standard height of a radiator is 36 or 38 inches, and, if possible, it is better not to exceed this.

For small radiators, it is better practice to use lower sections and increase the length; this makes the radiator slightly more efficient and gives a much better appearance.

To get the best results from wall radiators, they should be set out at least 1½ inches from the wall to allow a free circulation of air back of them. Patterns having cross-bars should be placed, if possible, with the bars in a vertical position, as their efficiency is impaired somewhat when placed horizontally.

Pipe Radiators. This type of radiator (see Fig. 19) is made up of wrought-iron pipes screwed into a cast-iron base. The pipes are either connected in pairs at the top by return bends, or each separate tube has a thin metal diaphragm passing up the center nearly to the top. It is necessary that a loop be formed, else a "dead end" would occur. This would become filled with air and prevent steam from entering, thus causing portions of the radiator to remain cold.

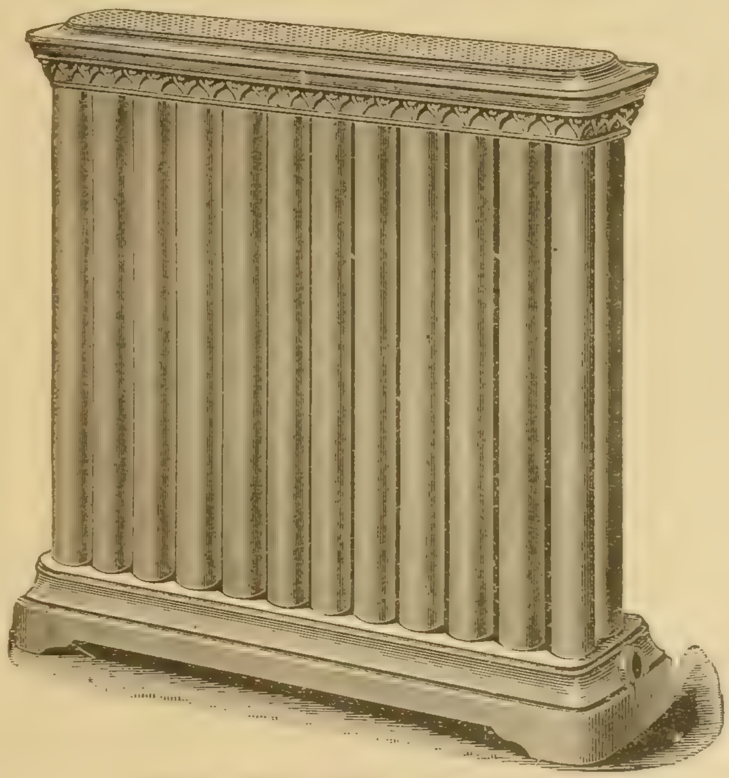


Fig. 19. Wrought-Iron Pipe Radiator.

Circulation Coils. These are usually made up of 1 or 1¼-inch wrought-iron pipe, and may be hung on the walls of a room by means of hook plates, or suspended overhead on hangers and rolls.

Fig. 20 shows a common form for schoolhouse and similar work; this coil is usually made of 1¼-inch pipe screwed into *headers* or *branch tees* at the ends, and is hung on the wall just below the windows. This is known as a *branch coil*. Fig. 21 shows a *trombone coil*, which is commonly used when the pipes cannot turn a corner, and where the entire coil must be placed upon one side of the room. Fig. 22

is called a *miter coil*, and is used under the same conditions as a trombone coil if there is room for the vertical portion. This form is not so pleasing in appearance as either of the other two, and is found only in factories or shops, where looks are of minor importance.

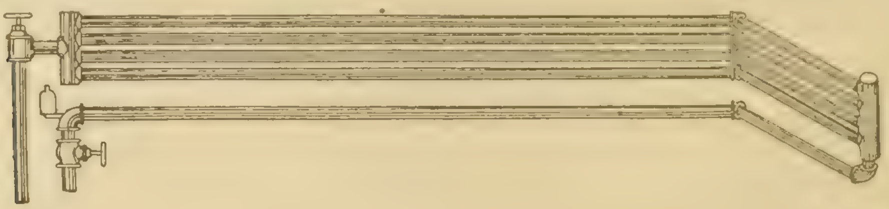


Fig. 20. Common Form of "Branch" Coil for Circulation of Direct Steam.

Overhead coils are usually of the miter form, laid on the side and suspended about a foot from the ceiling; they are less efficient than when placed nearer the floor, as the warm air stays at the ceiling and the lower part of the room is likely to remain cold. They are used only when wall coils or radiators would be in the way of fixtures, or when they would come below the water-line of the boiler if placed near the floor.

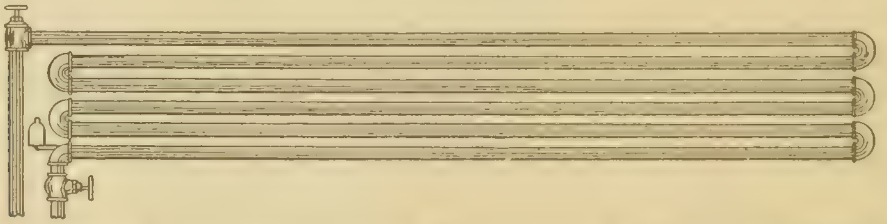


Fig. 21. "Trombone" Coil. Used where Entire Coil must be Placed on One Side of Room

When steam is first turned on a coil, it usually passes through a portion of the pipes first and heats them while the others remain cold and full of air. Therefore the coil must always be made up in such a way that each pipe shall have a certain amount of spring and may expand independently without bringing undue strains upon the others. Circulation coils should incline about 1 inch in 20 feet toward the

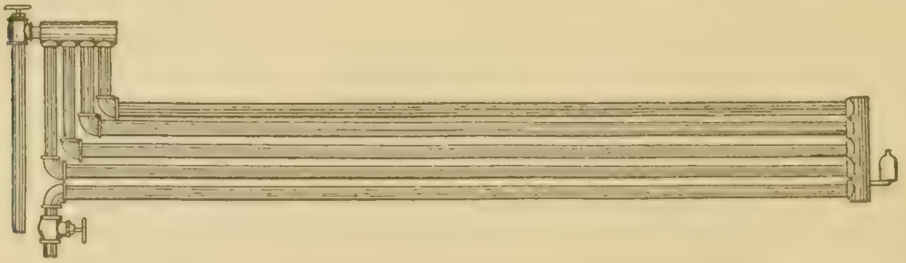


Fig. 22. "Miter" Coil. Adapted, like the "Trombone," Only to a Single Wall. Frequently Used in Factories and Shops.

return end in order to secure proper drainage and quietness of operation.

Efficiency of Radiators. The efficiency of a radiator—that is, the B. T. U. which it gives off per square foot of surface per hour—depends upon the difference in temperature between the steam in the radiator and the surrounding air, the velocity of the air over the radiator, and the quality of the surface, whether smooth or rough. In ordinary low-pressure heating, the first condition is practically constant; but the second varies somewhat with the pattern of the radiator. An open design which allows the air to circulate freely over the radiating surfaces, is more efficient than a closed pattern, and for this reason a pipe coil is more efficient than a radiator.

In a large number of tests of cast-iron and pipe radiators, working under usual conditions, the heat given off per square foot of surface per hour for each degree difference in temperature between the steam and surrounding air was found to average about 1.7 B. T. U. The temperature of steam at 3 pounds' pressure is 220 degrees, and 220—70 = 150, which may be taken as the average difference between the temperature of the steam and the air of the room, in ordinary low-pressure work. Taking the above results, we have 150 × 1.7 = 255 B. T. U. as the efficiency of an average cast-iron or pipe radiator. This, for convenient use, may be taken as 250. A circulation coil made up of pipes from 1 to 2 inches in diameter, will easily give off 300 B. T. U. under the same conditions; and a cast-iron wall radiator with ample space back of it should have an efficiency equal to that of a wall coil. While overhead coils have a higher efficiency than cast-iron radiators, their position near the ceiling reduces their effectiveness, so that in practice the efficiency should not be taken over 250 B. T. U. per hour at the most. Tabulating the above we have:

TABLE XIII

Efficiency of Radiators, Coils, etc.

TYPE OF RADIATING SURFACE	RADIATION PER SQUARE FOOT OF SURFACE PER HOUR	
Cast-Iron Sectional and Pipe Radiators	250	B. T. U.
Wall Radiators	300	"
Ceiling Coils	200 to 250	"
Wall Coils	300	"

If the radiator is for warming a room which is to be kept at a temperature above or below 70 degrees, or if the steam pressure is greater than 3 pounds, the radiating surface may be changed in the same proportion as the difference in temperature between the steam and the air.

For example, if a room is to be kept at a temperature of 60°, the efficiency of the radiator becomes $\frac{150}{140} \times 250 = 268$; that is, the efficiency varies directly as the difference in temperature between the steam and the air of the room. It is not customary to consider this unless the steam pressure should be raised to 10 or 15 pounds or the temperature of the rooms changed 15 or 20 degrees from the normal.

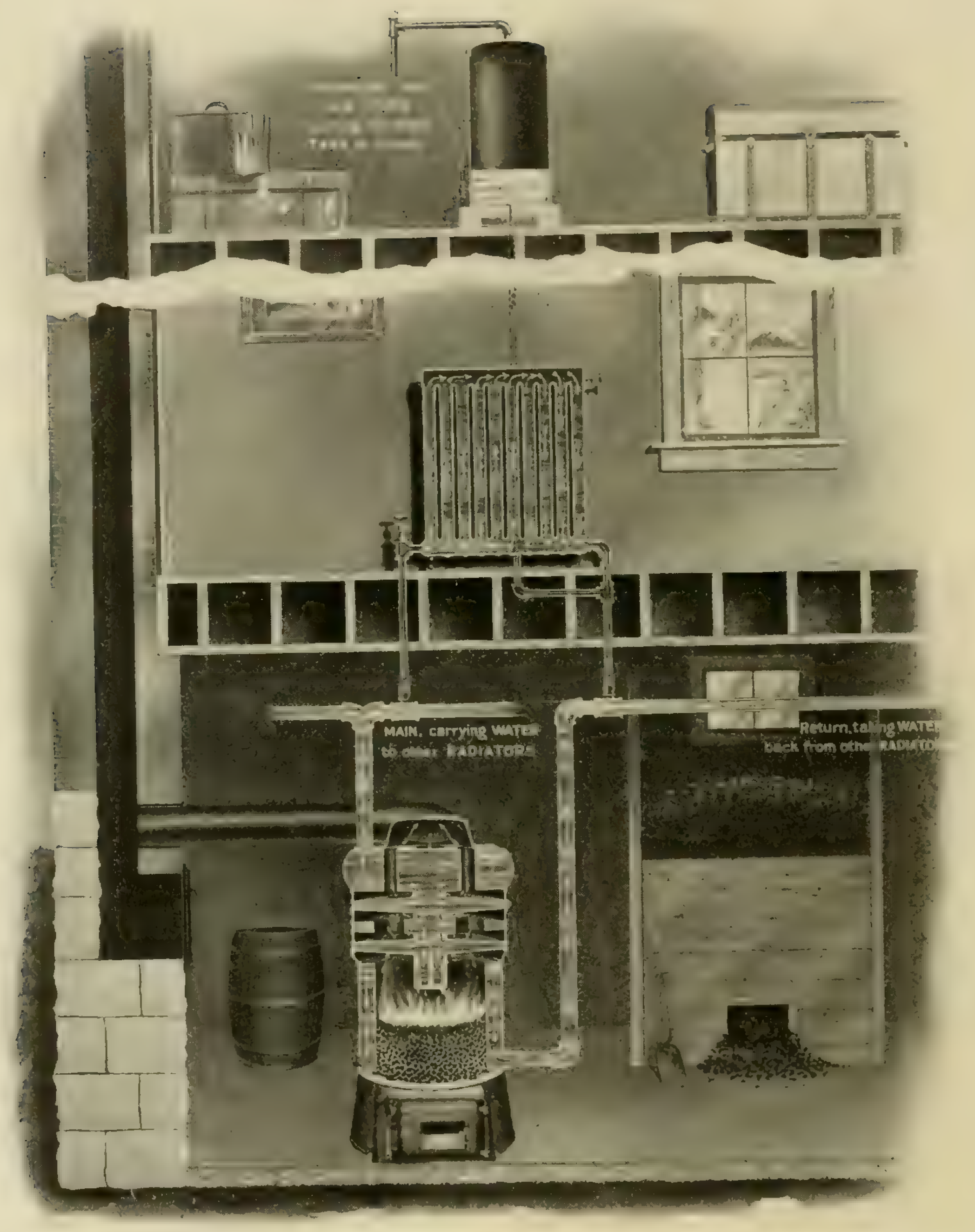
From the above it is easy to compute the size of radiator for any given room. First compute the heat loss per hour by conduction and leakage in the coldest weather; then divide the result by the efficiency of the type of radiator to be used. It is customary to make the radiators of such size that they will warm the rooms to 70 degrees in the coldest weather. As the low-temperature limit varies a good deal in different localities, even in the same State, the lowest temperature for which we wish to provide must be settled upon before any calculations are made. In New England and through the Middle and Western States, it is usual to figure on warming a building to 70 degrees when the outside temperature is from zero to 10 degrees below.

The different makers of radiators publish in their catalogues, tables giving the square feet of heating surface for different styles and heights, and these can be used in determining the number of sections required for all special cases.

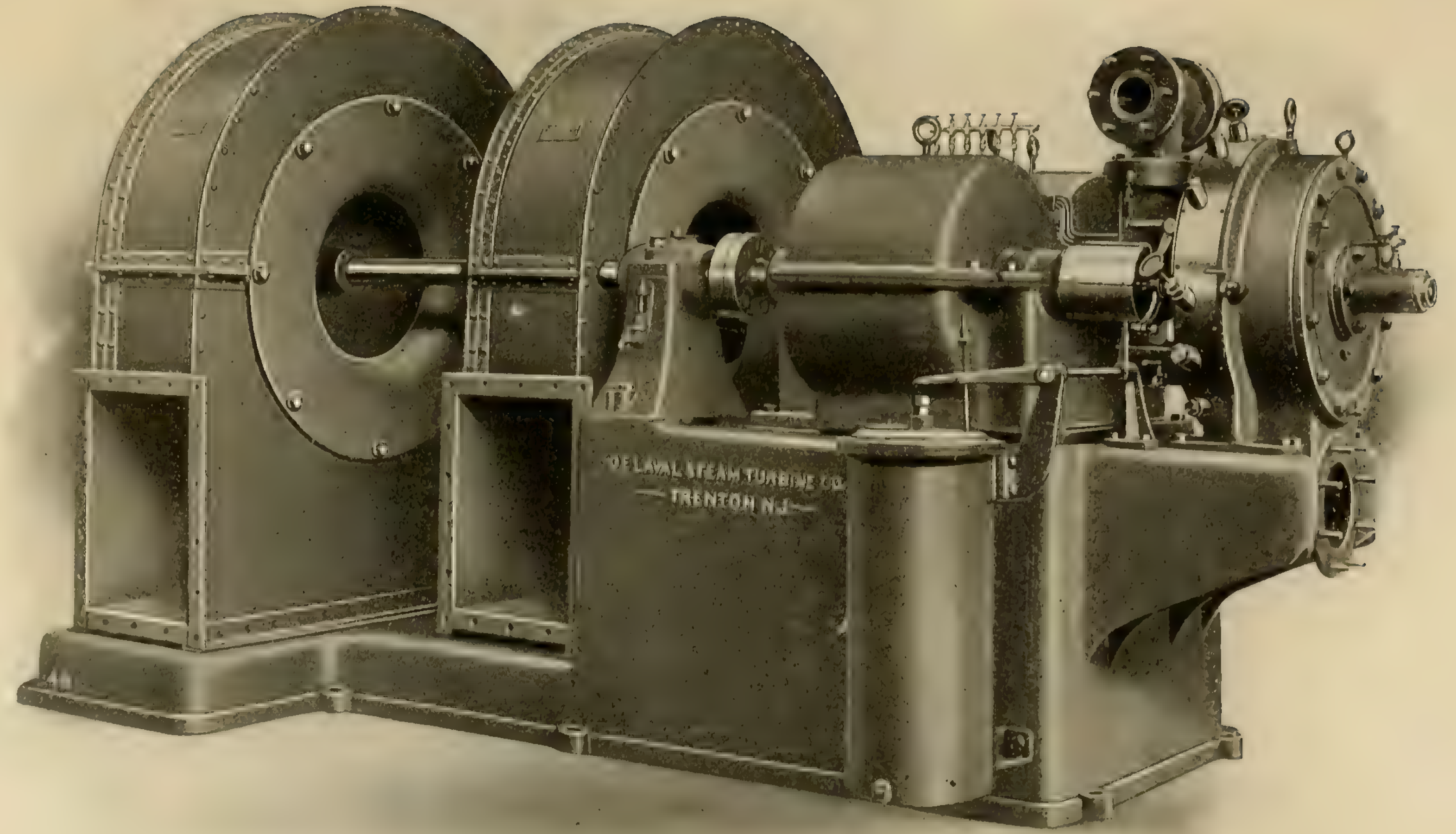
If pipe coils are to be used, it becomes necessary to reduce square feet of heating surface to linear feet of pipe; this can be done by means of the factors given below.

Square feet of heating surface ×	3	= linear	ft.	of	1 -in.	pipe
	2.3	= "		"	$1\frac{1}{4}$-in.	"
	2	= "		"	$1\frac{1}{2}$-in.	"
	1.6	= "		"	2 -in.	"

The size of radiator is made only sufficient to keep the room warm after it is once heated; and no allowance is made for *warming up*; that is, the heat given off by the radiator is just equal to that lost through walls and windows. This condition is offset in two ways—



PRINCIPLE OF HOT WATER HEATING ILLUSTRATED BY TRANSVERSE SECTIONAL VIEW SHOWING BOILER, RADIATOR AND EXPANSION TANK.
American Radiator Company.



150 H.P. DE LAVAL TURBINE BLOWER.

first, when the room is cold, the difference in temperature between the steam and the air of the room is greater, and the radiator is more efficient; and *second,* the radiator is proportioned for the coldest weather, so that for a greater part of the time it is larger than necessary.

EXAMPLES FOR PRACTICE

1. The heat loss from a room is 25,000 B. T. U. per hour in the coldest weather. What size of direct radiator will be required?

Ans. 100 square feet.

2. A schoolroom is to be warmed with circulation coils of $1\frac{1}{4}$-inch pipe. The heat loss is 30,000 B. T. U. per hour. What length of pipe will be required? Ans. 230 linear feet.

Location of Radiators. Radiators should, if possible, be placed in the coldest part of the room, as under windows or near outside doors. In living rooms it is often desirable to keep the windows free, in which case the radiators may be placed at one side. Circulation coils are run along the outside walls of a room under the windows. Sometimes the position of the radiators is decided by the necessary location of the pipe risers, so that a certain amount of judgment must be used in each special case as to the best arrangement to suit all requirements.

Systems of Piping. There are three distinct systems of piping, known as the *two-pipe system*, the *one-pipe relief system*, and the *one-pipe circuit system,* with various modifications of each and combinations of the different systems.

Fig. 23 shows the arrangement of piping and radiators in the two-pipe system. The steam main leads from the top of the boiler, and the branches are carried along near the basement ceiling. Risers are taken from the supply branches, and carried up to the radiators on the different floors; and return pipes are brought down to the return mains, which should be placed near the basement floor below the water-line of the boiler. Where the building is more than two stories high, radiators in similar positions on different floors are connected with the same riser, which may run to the highest floor; and a corresponding return drop connecting with each radiator is carried down beside the riser to the basement. A system in which the main horizontal returns are below the water-line of the boiler is said to have a *wet* or *sealed* return. If the returns are overhead and above the water-line, it is called a *dry* return. Where the steam is exposed to extended surfaces of water, as in overhead returns, where the condensation partially fills the pipes, there is likely to be cracking or *water-hammer,* due to the sudden condensation of the steam as it comes in contact with the cooler water. This is especially noticeable when steam is first turned into cold pipes and radiators, and the condensation is excessive. When dry returns are used, the pipes should be large and have a good pitch toward the boiler.

In the case of sealed returns, the only contact between the steam and standing water is in the vertical returns, where the exposed surfaces are very small (being equal to the sectional area of the pipes), and trouble from water-hammer is practically done away with. Dry returns should be given an incline of at least 1 inch in 10 feet, while for wet returns 1 inch in 20 or even 40 feet is ample. The ends of all steam mains and branches should be dripped into the returns. If the return is sealed, the drip may be directly connected as shown in Fig. 24; but if it is dry, the connection should be provided with a siphon loop as indicated in Fig. 25. The loop becomes filled with water, and prevents steam from flowing directly into the return. As the

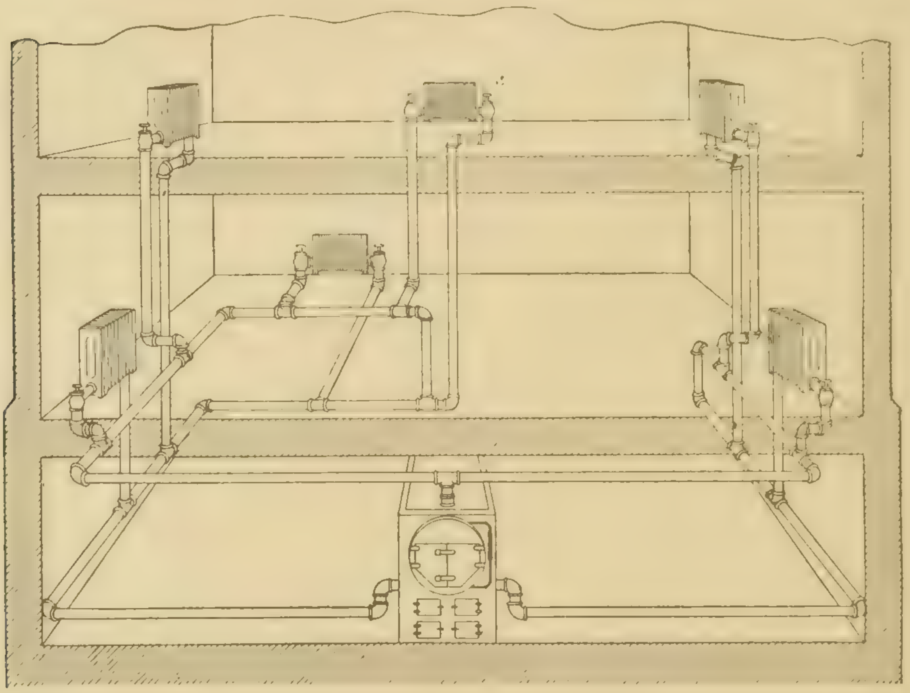


Fig. 23. Arrangement of Piping and Radiators in "Two-Pipe" System.

condensation collects in the loop, it overflows into the return pipe and is carried away. The return pipes in this case are of course filled with steam above the water; but it is steam which has passed through the radiators and their return connections, and is therefore at a slightly lower pressure; so that, if steam were admitted directly from the main, it would tend to hold back the water in more distant returns and cause surging and cracking in the pipes. Sometimes the boiler is at a lower level than the basement in which the returns are run, and it then becomes necessary to establish a *false* water-line. This is done by making connections as shown in Fig. 26.

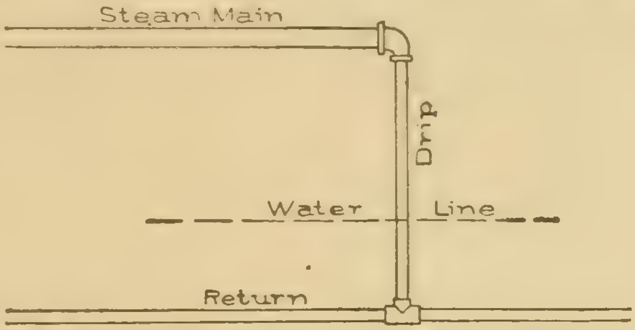


Fig. 24. Drip from Steam Main Connected Directly to Sealed Return.

It is readily seen that the return water, in order to reach the boiler, must flow through the trap, which raises the water-line or seal to the level shown by the dotted line. The balance pipe is to equalize the pressure above and below the water in the trap, and prevent siphonic action, which would tend to drain the water out of the return mains after a flow was once started.

The balance pipe, when possible, should be 15 or 20 feet in length, with a throttle-valve placed near its connection with the main. This valve should be opened just enough to allow the steam-pressure to act upon the air which occupies the space above the water in the trap; but it should not be opened sufficiently to allow the steam to enter in large volume and drive the air out. The success of this arrangement depends upon keeping a layer or cushion of cool air next to the surface of the water in the trap, and this is easily done by following the method here described.

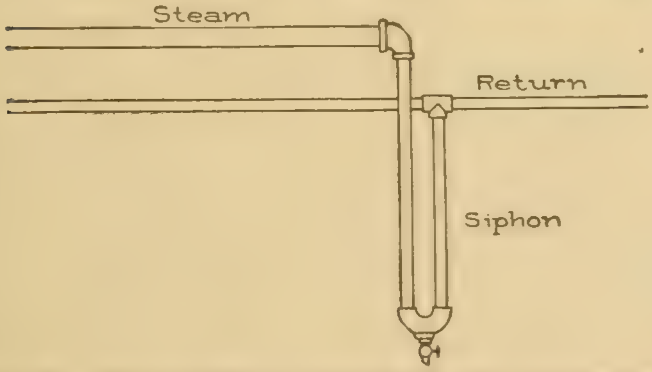


Fig 25. Use of Siphon in Connecting Drip from Steam Main to a "Dry" Return.

One-Pipe Relief System. In this system of piping, the radiators have but a single connection, the steam flowing in and the condensation draining out through the same pipe. Fig. 27 shows the method of running the pipes for this system. The steam main, as before, leads from the top of the boiler, and is carried to as high a point as the basement ceiling will allow; it then slopes downward with a grade of about 1 inch in 10 feet, and makes a circuit of the building or a portion of it.

Risers are taken from the top and carried to the radiators above, as in the two-pipe system; but in this case, the condensation flows back through the same pipe, and drains into the return main near the floor through drip connections which are made at frequent intervals. In a two-story building, the bottom of each riser to the second floor is dripped; and in larger buildings, it is customary to drip each riser that has more than one radiator connected with it. If the radiators are large and at a considerable distance from the next riser, it is better to make a drip connection for each radiator. When the return main is overhead, the risers should be dripped through siphon loops; but the ends of the branches should make direct connection with the returns. This is the reverse of the two-pipe system. In this case the lowest pressure is at the ends of the mains, so that steam introduced into the returns at these points will cause no trouble in the pipes connecting between these and the boiler.

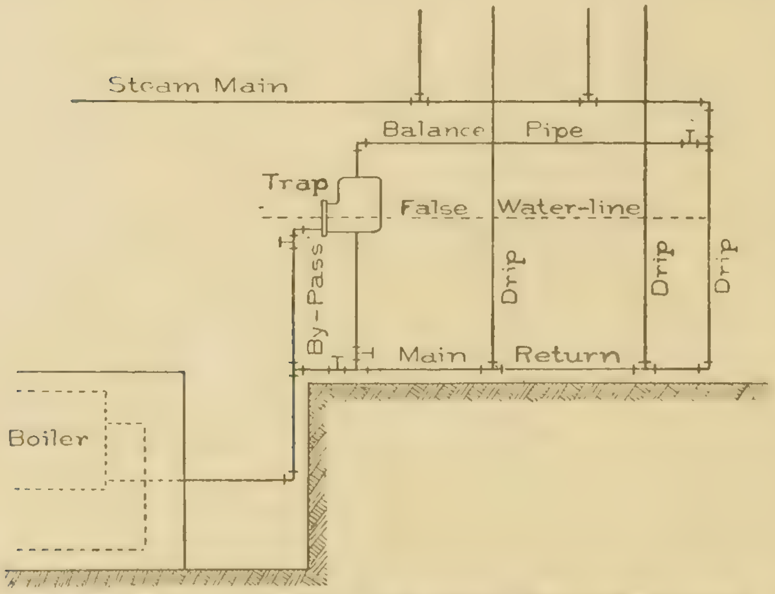


Fig. 26. Connections Made to Establish "False" Water-Line when Boiler is below Basement Level.

If no steam is allowed to enter the returns, a vacuum will be formed, and there will be no pressure to force the water back to the boiler. A check-valve should always be placed in the main return near the boiler, to prevent the water from flowing out in case of a vacuum being formed suddenly in the pipes.

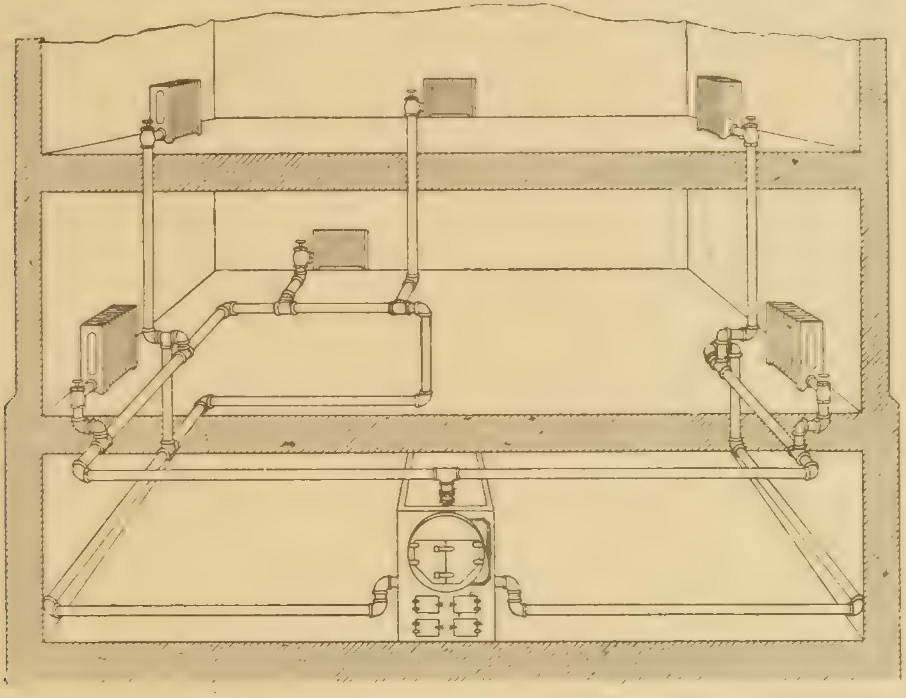


Fig. 27. Arrangement of Piping and Radiators in "One-Pipe Relief" System.

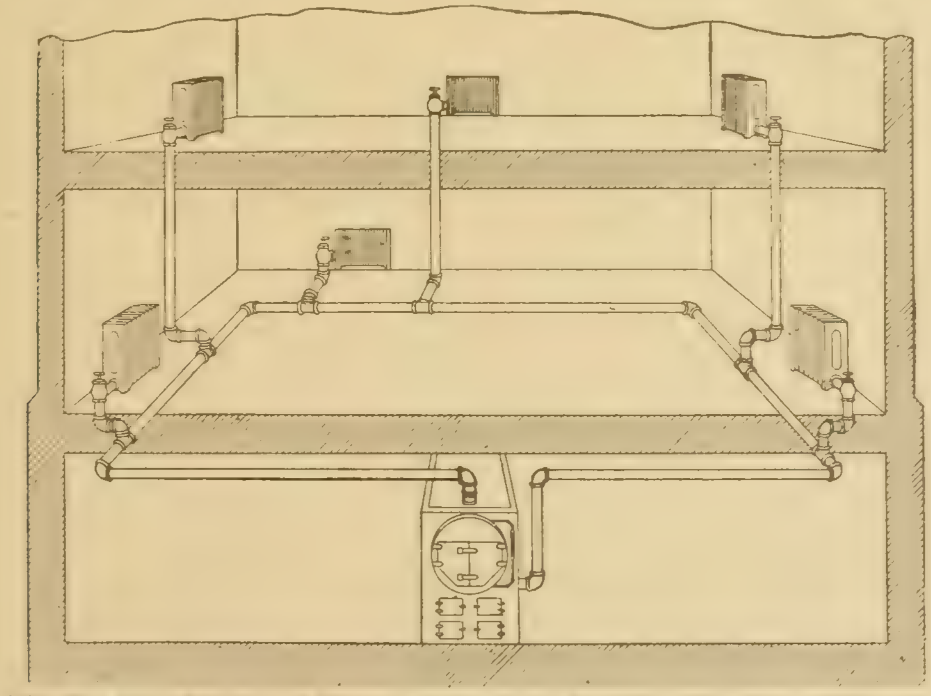


Fig. 28. Arrangement of Piping and Radiators in "One-Pipe Circuit" System.

There is but little difference in the cost of the two systems, as larger pipes and valves are required for the single-pipe method.

With radiators of medium size and properly proportioned connections, the single-pipe system in preferable, there being but one valve to operate and only one-half the number of risers passing through the lower rooms.

One=Pipe Circuit System. In this case, illustrated in Fig. 28, the steam main rises to the highest point of the basement, as before; and then, with a considerable pitch, makes an entire circuit of the building, and again connects with the boiler below the water-line. Single risers are taken from the top; and the condensation drains back through the same pipes, and is carried along with the flow of steam to the extreme end of the main, where it is returned to the boiler. The main is made large, and of the same size throughout its entire length. It must be given a good pitch to insure satisfactory results.

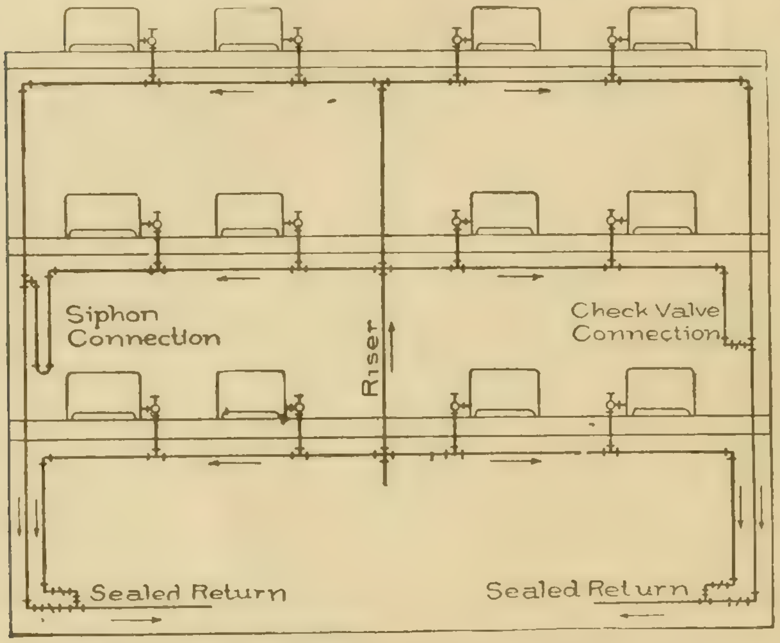


Fig. 29. "One-Pipe Circuit" System. Adapted to a Large Building.

One objection to a single-pipe system is that the steam and return water are flowing in opposite directions, and the risers must be made of extra large size to prevent any interference. This is overcome in large buildings by carrying a single riser to the attic, large enough to supply the entire building; then branching and running "drops" to the basement. In this system the flow of steam is downward, as well as that of water. This method of piping may be used with good results in two-pipe systems as well. Care must always be taken that no pockets or low points occur in any of the lines of pipe; but if for any reason they cannot be avoided, they should be carefully drained.

A modification of this system, adapting it to large buildings, is shown in diagram in Fig. 29. The riser shown in this case is one of several, the number depending upon the size of the building; and may be supplied at either bottom or top as most desirable. If steam is supplied at the bottom of the riser, as shown in the cut, all of the drip connections with the return drop, except the upper one, should be sealed with either a siphon loop or a check-valve, to prevent the steam from short-circuiting and holding back the condensation in the returns above. If an overhead supply is used, the arrangement should be the reverse; that is, all return connections should be sealed except the lowest.

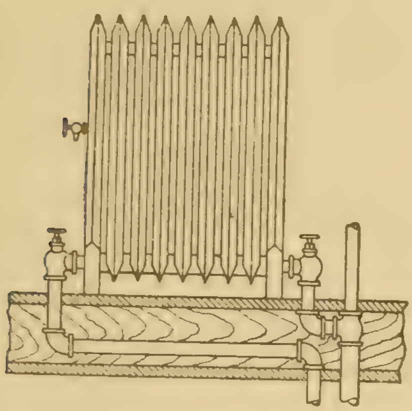


Fig. 30. "Two-Pipe" Connection of Radiator to Riser and Return.

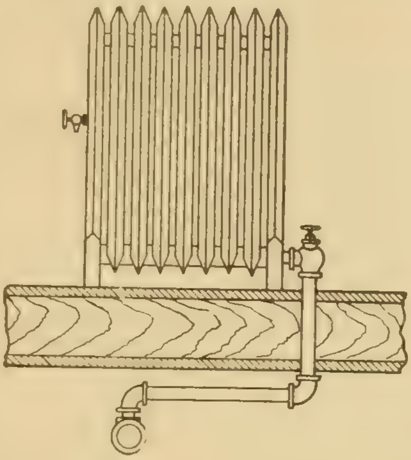


Fig. 31. "One-Pipe" Connection of Radiator to Basement Main.

Sometimes a separate drip is carried down from each set of radiators, as shown on the lower story, being connected with the main return below the water-line of the boiler. In case this is done, it is well to provide a check-valve in each drip below the water-line.

In buildings of any considerable size, it is well to divide the piping system into sections by means of valves placed in the corresponding supply and return branches. These are for use in case of a break in any part of the system, so that it will be necessary to shut off only a small part of the heating system during repairs. In tall buildings, it is customary to place valves at the top and bottom of each riser, for the same purpose.

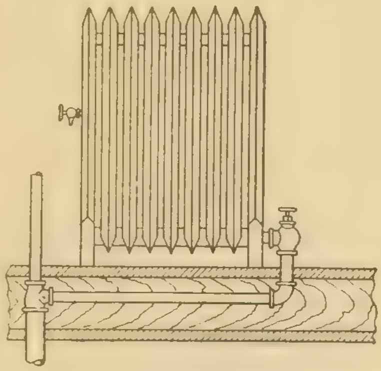


Fig. 32. "One-Pipe" Connection of Radiator to Riser.

Radiator Connections. Figs. 30, 31, and 32 show the common methods of making connections between supply pipes and radiators. Fig. 30 shows a two-pipe connection with a riser; the return is carried down to the main below. Fig. 31 shows a single-pipe connection with a basement main; and Fig. 32, a single connection with a riser.

Care must always be taken to make the horizontal part of the piping between the radiator and riser as short as possible, and to give it a good pitch toward the riser. There are various ways of making these connections, especially suited to different conditions; but the examples given serve to show the general principle to be followed.

Figs. 20, 21, and 22 show the common methods of making steam and return connections with circulation coils. The position of the air-valve is shown in each case.

Expansion of Pipes. Cold steam pipes expand approximately 1 inch in each 100 feet in length when low-pressure steam is turned into them; so that, in laying out a system of piping, we must arrange it in such a manner that there will be sufficient "spring" or "give" to the pipes to prevent injurious strains. This is done by means of offsets and bends. In the case of larger pipes this simple method will not be sufficient, and swivel or slip joints must be used to take up the expansion.

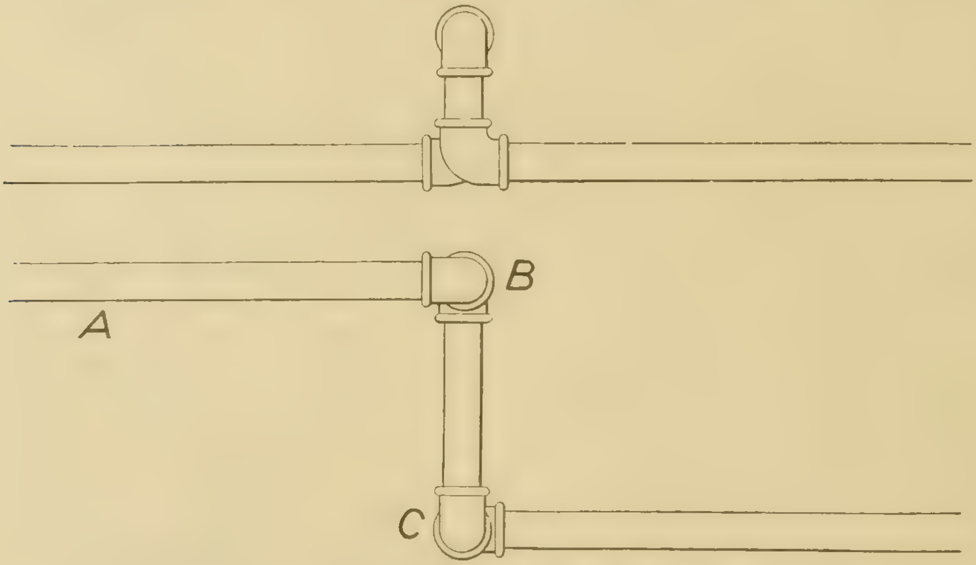


Fig. 33. Elevation and Plan of Swivel-Joint to Counteract Effects of Expansion and Contraction in Pipes.

The method of making up a swivel-joint is shown in Fig. 33. Any lengthening of the pipe *A* will be taken up by slight turning or swivel movements at the points *B* and *C*. A slip-joint is shown in

Fig. 34. The part *c* slides inside the shell *d*, and is made steam-tight by a stuffing-box, as shown. The pipes are connected at the flanges *A* and *B*.

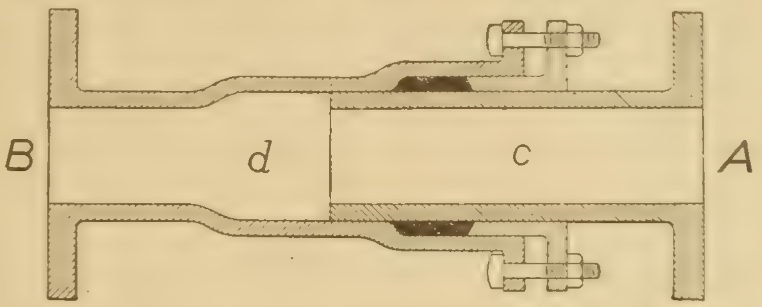


Fig. 34. "Slip-Joint" Connection to Take Care of Expansion and Contraction of Pipes.

When pipes pass through floors or partitions, the woodwork should be protected by galvanized-iron sleeves having a diameter from ¾ to 1 inch greater than the pipe. Fig. 35 shows a form of adjustable floor-sleeve which may be lengthened or shortened to conform to the thickness of floor or partition. If plain sleeves are used, a plate should be placed around the pipe where it passes through the floor or partition. These are made in two parts so that they may be put in place after the pipe is hung. A plate of this kind is shown in Fig. 36.

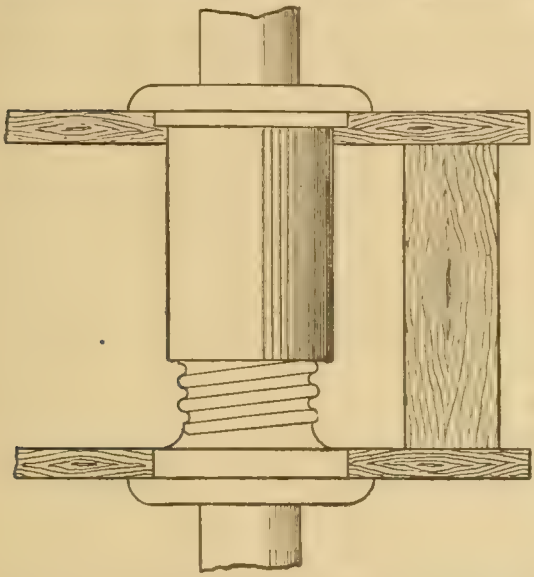


Fig. 35. Adjustable Metal Sleeve for Carrying Pipe through Floor or Partition.

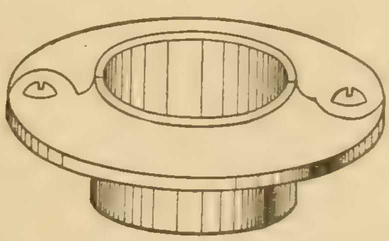


Fig. 36. Floor-Plate Adjusted to Plain Sleeve for Carrying Pipe through Floor or Partition.

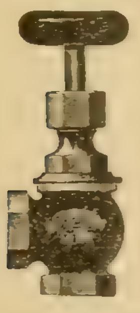


Fig. 37. Angle Valve.

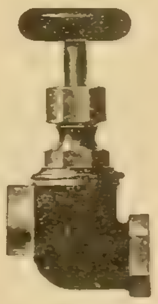


Fig. 38. Offset Valve.

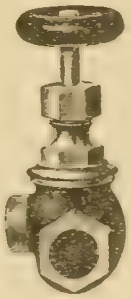


Fig. 39. Corner Valve.

Valves for Radiator Connections.

Valves. The different styles commonly used for radiator connections are shown in Figs. 37, 38, and 39, and are known as *angle*, *offset*, and *corner* valves, respectively. The first is used when the radiator is at the top of a riser or when the connections are like those shown in Figs. 30, 31, and 32; the second is used when the connection between the riser and radiator is above the floor; and the third, when the radiator has to be set close in the corner of a room and there is not space for the usual connection.

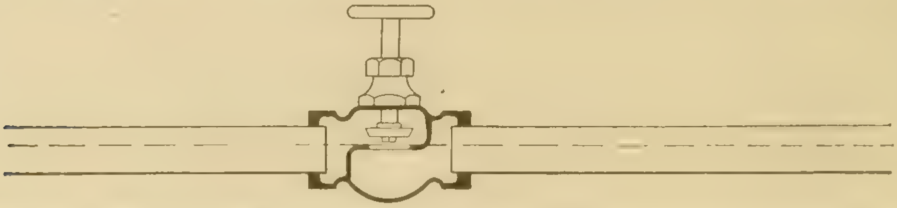


Fig. 40. Indicating Effect of Using Globe Valve on Horizontal Steam Supply Pipe or Dry Return.

A *globe* valve should never be used in a horizontal steam supply or dry return. The reason for this is plainly shown in Fig. 40. In order for water to flow through the valve, it must rise to a height shown by the dotted line, which would half fill the pipes, and cause serious trouble from water-hammer. The gate valve shown in Fig. 41 does not have this undesirable feature, as the opening is on a level with the bottom of the pipe.

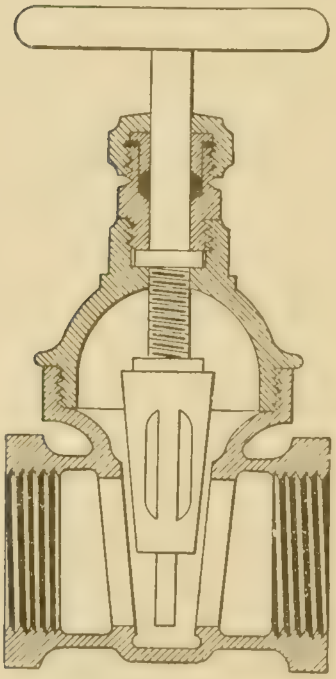


Fig. 41. Gate Valve.

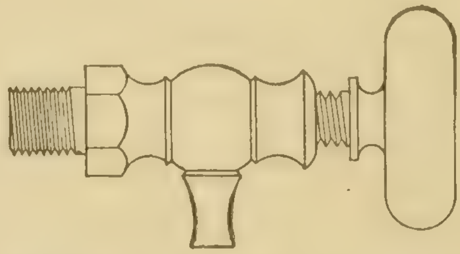


Fig. 42. Simplest Form of Air-Valve. Operated by Hand.

Air-Valves. Valves of various kinds are used for freeing the radiators from air when steam is turned on. Fig. 42 shows the simplest form, which is operated by hand. Fig. 43 is a type of automatic valve, consisting of a shell, which is attached to the radiator. *B* is a small opening which may be closed by the spindle *C*, which is provided with a conical end. *D* is a strip composed of a layer of iron or steel and one of brass soldered or brazed together. The action of the valve is as follows: when the radiator is cold and filled with air the valve stands as shown in the cut. When steam is turned on, the air is driven out through the opening *B*. As soon as this is expelled and steam strikes the strip *D*, the two prongs spring apart owing to the unequal expansion of the two metals due to the heat of the steam. This raises the spindle *C*, and closes the opening so that no steam can escape. If air should collect in the valve, and the metal strip become cool, it would contract, and the spindle would drop and allow the air to escape through *B* as before. *E* is an adjusting nut. *F* is a float attached to the spindle, and is supposed, in case of a sudden rush of water with the air, to rise and close the opening; this action, however, is somewhat uncertain, especially if the pressure of water continues for some time.

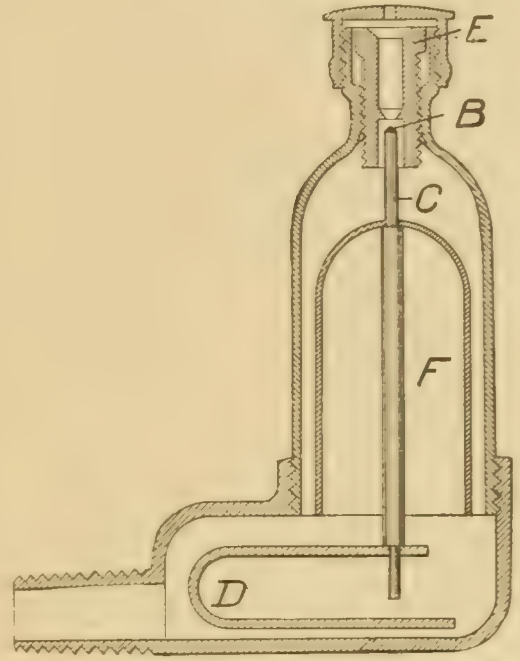


Fig. 43. Radiator Automatic Air-Valve. Operated by Metal Strip *D*, Consisting of Two Pieces of Metal of Unequal Expansive Power.

There are other types of valves acting on the same principle. The valve shown in Fig. 44 is closed by the expansion of a piece of vulcanite instead of a metal strip, and has no water float.

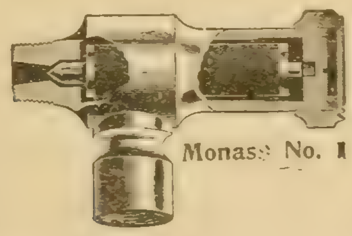


Fig. 44. Automatic Air-Valve. Closed by Expansion of a Piece of Vulcanite.

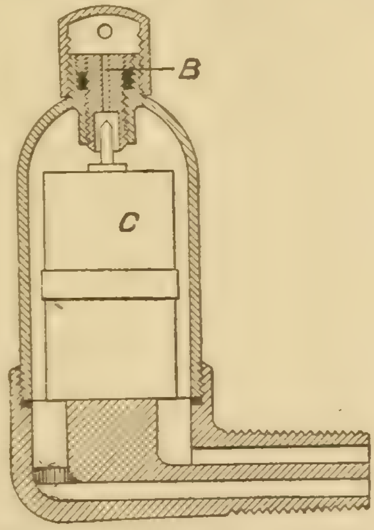


Fig. 45. Automatic Air-Valve. Operated by Expansion of Drum *C* Due to Vaporization of Alcohol with which it is Partly Filled.

The valve shown in Fig. 45 acts on a somewhat different principle. The float *C* is made of thin brass, closed at top and bottom, and is partially filled with wood alcohol. When steam strikes the float, the alcohol is vaporized, and creates a pressure sufficient to bulge out the ends slightly, which raises the spindle and closes the opening *B*.

Fig. 46 shows a form of so-called *vacuum valve.* It acts in a similar manner to those already described, but has in addition a ball check which prevents the air from being drawn into the radiator, should the steam go down and a vacuum be formed. If a partial vacuum exists in the boiler and radiators, the boiling point, and consequently the temperature of the steam, are lowered, and less heat is given off by the radiators. This method of operating a heating plant is sometimes advocated for spring and fall, when little heat is required, and when steam under pressure would overheat the rooms.

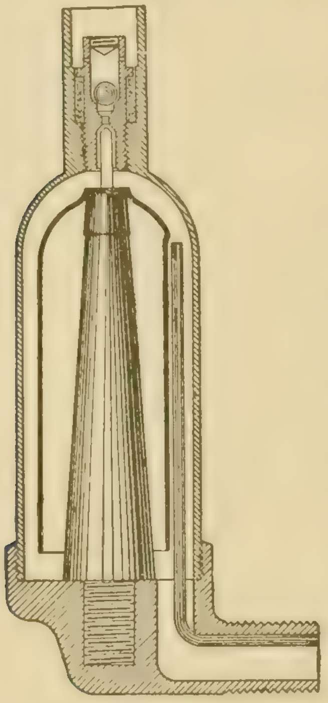


Fig. 46. Vacuum Valve.

Pipe Sizes. The proportioning of the steam pipes in a heating plant is of the greatest importance, and should be carefully worked out by methods which experience has proved to be correct. There are several ways of doing this; but for ordinary conditions, Tables XIV, XV, and XVI have given excellent results in actual practice. They have been computed from what is known as D'Arcy's formula, with suitable corrections made for actual working conditions. As the computations are somewhat complicated, only the results will be given here, with full directions for their proper use.

Table XIV gives the flow of steam in pounds per minute for pipes of different diameters and with varying drops in pressure between the supply and discharge ends of the pipe. These quantities are for pipes 100 feet in length; for other lengths the results must be corrected by the factors given in Table XVI. As the length of pipe increases, friction becomes greater, and the quantity of steam discharged in a given time is diminished.

Table XIV is computed on the assumption that the drop in

TABLE XIV

Flow of Steam in Pipes of Various Sizes, with Various Drops in Pressure between Supply and Discharge Ends

Calculated for 100-Foot Lengths of Pipe

Diam. of Pipe	Drop in Pressure (Pounds)								
	¼	½	¾	1	1½	2	3	4	5
1	.44	.63	.78	91	1.13	1.31	1.66	1.97	2.26
1¼	.81	1.16	1.43	1.66	2.05	2.39	3.02	3.59	4.12
1½	1.06	1.89	2.34	2.71	3.36	3.92	4.94	5.88	6.75
2	2.93	4.17	5.16	5.99	7.43	8.65	10.9	13.0	14.9
2½	5.29	7.52	9.32	10.8	13.4	15.6	19.7	23.4	26.9
3	8.61	12.3	15.2	17.6	21.8	25.4	32	31.8	43.7
3½	12.9	18.3	22.6	26.3	32.5	37.9	47.8	56.9	65.3
4	18 1	25.7	31.8	36.9	45.8	53.3	67.2	80.1	91.9
5	32.2	45.7	56.6	65.7	81.3	94.7	120	142	163
6	51.7	73.3	90.9	106	131	152	192	229	262
7	76.7	109	135	157	194	226	285	339	390
8	108	154	190	222	274	319	402	478	549
9	147	209	258	299	371	432	545	649	745
10	192	273	339	393	487	567	715	852	977
12	305	434	537	623	771	899	1,130	1,350	1,550
15	535	761	942	1,090	1,350	1,580	1,990	2,370	2,720

pressure between the two ends of the pipe equals the initial pressure. If the drop in pressure is less than the initial pressure, the actual discharge will be slightly greater than the quantities given in the table;

TABLE XV

Factors for Calculating Flow of Steam in Pipes under Initial Pressures above Five Pounds

To be used in connection with Table XIV

Drop in Pressure in Pounds	Initial Pressure (Pounds)					
	10	20	30	40	60	80
¼	1.27	1.49	1.68	1.84	2.13	2.38
½	1.26	1.48	1.66	1.83	2.11	2.36
1	1.24	1.46	1.64	1.80	2.08	2.32
2	1.21	1.41	1.59	1.75	2.02	2.26
3	1.17	1.37	1.55	1.70	1.97	2.20
4	1.14	1.34	1.51	1.66	1.92	2.14
5	1.12	1.31	1.47	1.62	1.87	2.09

but this difference will be small for pressures up to 5 pounds, and may be neglected, as it is on the side of safety. For higher initial pressures, Table XV has been prepared. This is to be used in connection with Table XIV as follows: First find from Table XIV the quantity of steam which will be discharged through the given diameter of pipe

TABLE XVI

Factors for Calculating Flow of Steam in Pipes of Other Lengths than 100 Feet

Feet	Factor	Feet	Factor	Feet	Factor	Feet	Factor
10	3.16	120	.91	275	.60	600	.40
20	2.24	130	.87	300	.57	650	.39
30	1.82	140	.84	325	.55	700	.37
40	1.58	150	.81	350	.53	750	.36
50	1.41	160	.79	375	.51	800	.35
60	1.29	170	.76	400	.50	850	.34
70	1.20	180	.74	425	.48	900	.33
80	1.12	190	.72	450	.47	950	.32
90	1.05	200	.70	475	.46	1,000	.31
100	1.00	225	.66	500	.45		
110	.95	250	.63	550	.42		

with the assumed drop in pressure; then look in Table XV for the factor corresponding with the assumed drop and the higher initial pressure to be used. The quantity given in Table XIV, *multiplied by* this factor, will give the actual capacity of the pipe under the given conditions.

Example. What weight of steam will be discharged through a 3-inch pipe 100 feet long, with an initial pressure of 60 pounds and a drop of 2 pounds?

Looking in Table XIV, we find that a 3-inch pipe will discharge 25.4 pounds of steam per minute with a 2-pound drop. Then looking in Table XV, we find the factor corresponding to 60 pounds initial pressure and a drop of 2 pounds to be 2.02. Then according to the rule given, 25.4 × 2.02 = 51.3 pounds, which is the capacity of a 3-inch pipe under the assumed conditions.

Sometimes the problem will be presented in the following way: What size of pipe will be required to deliver 80 pounds of steam a distance of 100 feet with an initial pressure of 40 pounds and a drop of 3 pounds?

We have seen that the higher the initial pressure with a given drop, the greater will be the quantity of steam discharged; therefore a smaller pipe will be required to deliver 80 pounds of steam at 40 pounds than at 3 pounds initial pressure. From Table XV, we find that a given pipe will discharge 1.7 times as much steam per minute with a pressure of 40 pounds and a drop of 3 pounds, as it would with a pressure of 3 pounds, dropping to zero. From this it is evident that if we divide 80 by 1.7 and look in Table XIV under "3 pounds drop" for the result thus obtained, the size of pipe corresponding will be that required. Now, $80 \div 1.7 = 47$. The nearest number in the table marked "3 pounds drop" is 47.8, which corresponds to a 3½-inch pipe, which is the size required.

These conditions will seldom be met with in low-pressure heating, but apply more particularly to combination power and heating plants, and will be taken up more fully under that head. For lengths of pipe other than 100 feet, multiply the quantities given in Table XIV by the factors found in Table XVI.

Example—What weight of steam will be discharged per minute through a 3½-inch pipe 450 feet long, with a pressure of 5 pounds and a drop of ½ pound?

Table XIV, which may be used for all pressures below 10 pounds, gives for a 3½-inch pipe 100 feet long, a capacity of 18.3 pounds for the above conditions. Looking in Table XVI, we find the correction factor for 450 feet to be .47. Then $18.3 \times .47 = 8.6$ pounds, the quantity of steam which will be discharged if the pipe is 450 feet long.

Examples involving the use of Tables XIV, XV, and XVI in combination, are quite common in practice. The following example will show the method of calculation:

What size of pipe will be required to deliver 90 pounds of steam per minute a distance of 800 feet, with an initial pressure of 80 pounds and a drop of 5 pounds?

Table XVI gives the factor for 800 feet as .35, and Table XV, that for 80 pounds pressure and 5 pounds drop, as 2.09. Then $\frac{90}{.35 \times 2.09} = 123$, which is the equivalent quantity we must look for in Table XIV. We find that a 4-inch pipe will discharge 91.9 pounds, and a 5-inch pipe 163 pounds. A 4½-inch pipe is not commonly carried in stock, and we should probably use a 5-inch in this case, unless it was decided to use a 4-inch and allow a slightly greater drop in pressure. In ordinary heating work, with pressures varying from 2 to 5 pounds, a drop of ¼ pound in 100 feet has been found to give satisfactory results.

In computing the pipe sizes for a heating system by the above methods, it would be a long process to work out the size of each branch separately. Accordingly Table XVII has been prepared for ready use in low-pressure work.

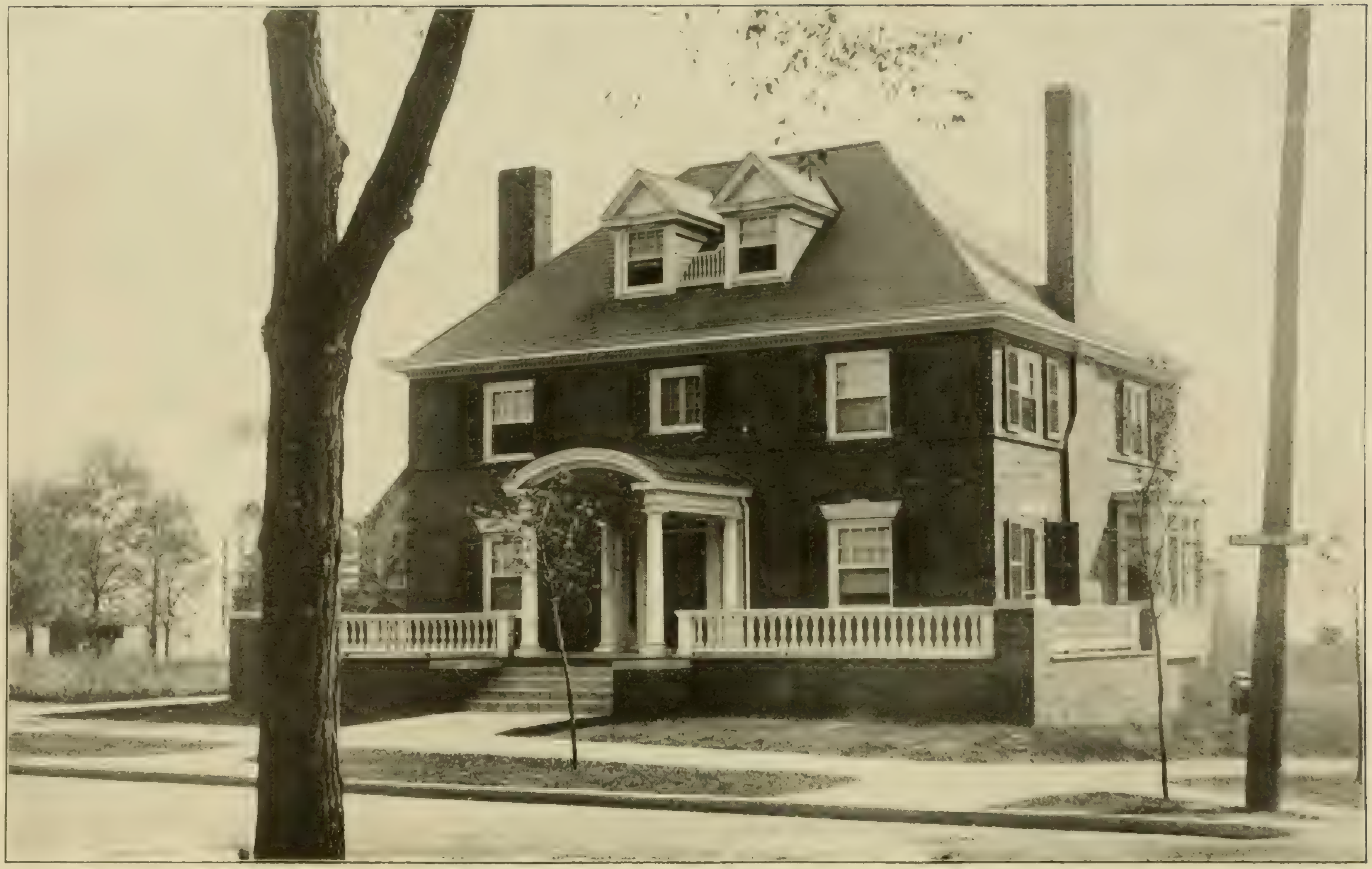
As most direct heating systems, and especially those in schoolhouses, are made up of both radiators and circulation coils, an efficiency of 300 B. T. U. has been taken for direct radiation of whatever variety, no distinction being made between the different kinds. This gives a slightly larger pipe than is necessary for cast-iron radiators; but it is probably offset by bends in the pipes, and in any case gives a slight factor of safety. We find from a steam table that the *latent heat* of steam at 20 pounds above a vacuum (which corresponds to 5 pounds' gauge-pressure) is 954 + B. T. U.—which means that, for every pound of steam condensed in a radiator, 954 B. T. U. are given off for warming the air of the room. If a radiator has an efficiency of 300 B. T. U., then each square foot of surface will condense 300 ÷ 954 = .314 pound of steam per hour; so that we may assume in round numbers a condensation of $\frac{1}{3}$ of a pound of steam per hour for each square foot of direct radiation, when computing the sizes of steam pipes in low-pressure heating. Table XVII has been calculated on this assumption, and gives the square feet of heating surface which different sizes of pipe will supply, with drops in pressure of $\frac{1}{4}$ and $\frac{1}{2}$ pounds in each 100 feet of pipe. The former should be used for pressures from 1 to 5 pounds, and the latter may be used for pressures over 5 pounds, under ordinary conditions. The sizes of long mains and special pipes of large size should be proportioned directly from Tables XIV, XV, and XVI.

TABLE XVII

Heating Surface Supplied by Pipes of Various Sizes

Length of Pipe, 100 Feet

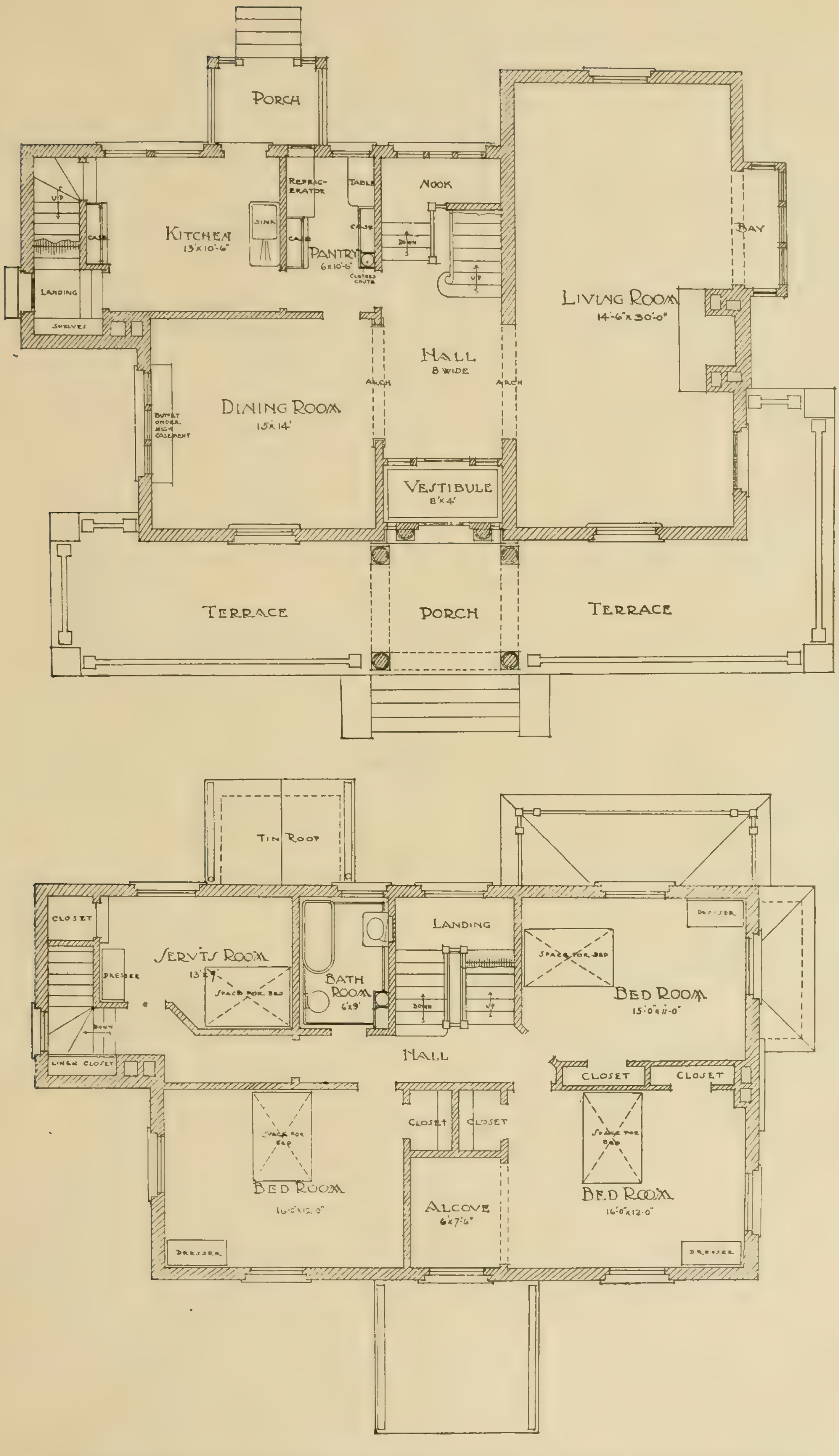
Size of Pipe	Square Feet of Heating Surface	
	$\frac{1}{4}$ Pound Drop	$\frac{1}{2}$ Pound Drop
1	80	114
$1\frac{1}{4}$	145	210
$1\frac{1}{2}$	190	340
2	525	750
$2\frac{1}{2}$	950	1,350
3	1,550	2,210
$3\frac{1}{2}$	2,320	3,290
4	3,250	4,620
5	5,800	8,220
6	9,320	13,200
7	13,800	19,620
8	19,440	27,720



HOUSE FOR MR. R. H. CAMPBELL, PEORIA, ILL.

Herbert E. Hewitt and Frederic J. Klein, Architects, Peoria, Ill.

Exterior, Brick Veneer of Clinker Brick; Slate Roof. Built in 1905. Cost, $6,000, Including Plumbing and Furnace Heating. First Story, Oak Trim and Oak Floors; Second Story, White Enamel With Birch Doors. Plans of First and Second Floors Shown on Opposite Page.



FIRST AND SECOND STORY PLANS OF HOUSE FOR MR. R. H. CAMPBELL, PEORIA, ILL.

Herbert E. Hewitt, & Frederic J. Klein, Architects, Peoria, Ill.
Front View of House Shown on Opposite Page.

Where the two-pipe system is used and the radiators have separate supply and return pipes, the risers or vertical pipes may be taken from Table XVII; but if the single-pipe system is used, the risers must be increased in size, as the steam and water are flowing in opposite directions and must have plenty of room to pass each other. It is customary in this case to base the computation on the velocity of the steam in the pipes, rather than on the drop in pressure. Assuming, as before, a condensation of one-third of a pound of steam per hour per square foot of radiation, Tables XVIII and XIX have been prepared for velocities of 10 and 15 feet per second. The sizes given in Table XIX have been found sufficient in most cases; but the larger sizes, based on a flow of 10 feet per second, give greater safety and should be more generally used. The size of the largest riser should usually be limited to 2½ inches in school and dwelling-house work, unless it is a special pipe carried up in a concealed position. If the length of riser is short between the lowest radiator and the main, a higher velocity of 20 feet or more may be allowed through this portion, rather than make the pipe excessively large.

TABLE XVIII TABLE XIX

Radiating Surface Supplied by Steam Risers

10 Feet per Second Velocity		15 Feet per Second Velocity	
Size of Pipe	Sq. Feet of Radiation	Size of Pipe	Sq. Feet of Radiation
1 in.	30	1 in.	50
1¼ "	60	1¼ "	90
1½ "	80	1½ "	120
2 "	130	2 "	200
2½ "	190	2½ "	290
3 "	290	3 "	340
3½ "	390	3½ "	590

EXAMPLES FOR PRACTICE

1. How many pounds of steam will be delivered per minute, through a 3½-inch pipe 600 feet long, with an initial pressure of 5 pounds and a drop of ½ pound? Ans. 7.32 pounds.

2. What size pipe will be required to deliver 25.52 pounds of steam per minute with an initial pressure of 3 pounds and a drop of ¼ pound, the length of the pipe being 50 feet? Ans. 4-inch.

3. Compute the size of pipe required to supply 10,000 square feet of direct radiation (assume ⅓ of a pound of steam per square

foot per hour) where the distance to the boiler house is 300 feet, and the pressure carried is 10 pounds, allowing a drop in pressure of 4 pounds. Ans. 5-inch (this is slightly larger than is required, while a 4-inch is much too small).

TABLE XX
Sizes of Returns for Steam Pipes (in Inches)

Diameter of Steam Pipe	Diameter of Dry Return	Diameter of Sealed Return
1	1	¾
1¼	1	1
1½	1¼	1
2	1½	1¼
2½	2	1½
3	2½	2
3½	2½	2
4	3	2½
5	3	2½
6	3½	3
7	3½	3
8	4	3½
9	5	3½
10	5	4
12	6	5

Returns. The size of return pipes is usually a matter of custom and judgment rather than computation. It is a common rule among steamfitters to make the returns one size smaller than the corresponding steam pipes. This is a good rule for the smaller sizes, but gives a larger return than is necessary for the larger sizes of pipe. Table XX gives different sizes of steam pipes with the corresponding diameters for dry and sealed returns.

TABLE XXI
Pipe Sizes for Radiator Connections

Square Feet of Radiation		Steam	Return
Two-Pipe	10 to 30	¾ inch	¾ inch
	30 to 48	1 "	¾ "
	48 to 96	1¼ "	1 "
	96 to 150	1½ "	1¼ "
Single-Pipe	10 to 24	1 inch	
	24 to 60	1¼ "	
	60 to 80	1½ "	
	80 to 130	2 "	

The length of run and number of turns in a return pipe should be noted, and any unusual conditions provided for. Where the condensation is discharged through a trap into a lower pressure, the sizes given may be slightly reduced, especially among the larger sizes, depending upon the differences in pressure.

Radiators are usually tapped for pipe connections as shown in Table XXI, and these sizes may be used for the connections with the mains or risers.

Boiler Connections. The steam main should be connected to the rear nozzle, if a tubular boiler is used, as the boiling of the water is less violent at this point and dryer steam will be obtained. The shut-off valve should be placed in such a position that pockets for the accumulation of condensation will be avoided. Fig. 47 shows a good position for the valve.

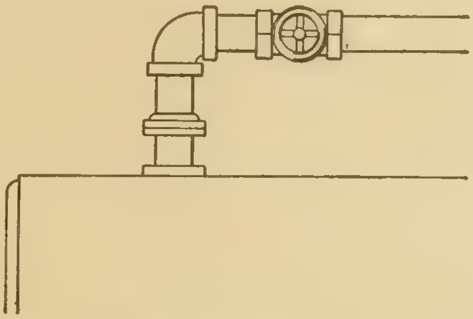


Fig. 47. Good Position for Shut-Off Valve.

The size of steam connection may be computed by means of the methods already given, if desired. But for convenience the sizes given in Table XXII may be used with satisfactory results for the short runs between the boilers and main header.

TABLE XXII
Pipe Sizes from Boiler to Main Header

Diameter of Boiler	Size of Steam Pipe
36 inches	3 inches
42 "	4 "
48 "	4 "
54 "	5 "
60 "	5 "
66 "	6 "
72 "	6 "

The return connection is made through the blow-off pipe, and should be arranged so that the boiler can be blown off without draining the returns. A check-valve should be placed in the main return, and a plug-cock in the blow-off pipe. Fig. 48 shows in plan a good arrangement for these connections.

The feed connections, with the exception of that part exposed in the smoke-bonnet, are always made of brass in the best class of work. The small section referred to should be of extra heavy wrought iron. The branch to each boiler should be provided with a gate or globe valve and a check-valve, the former being placed next to the boiler.

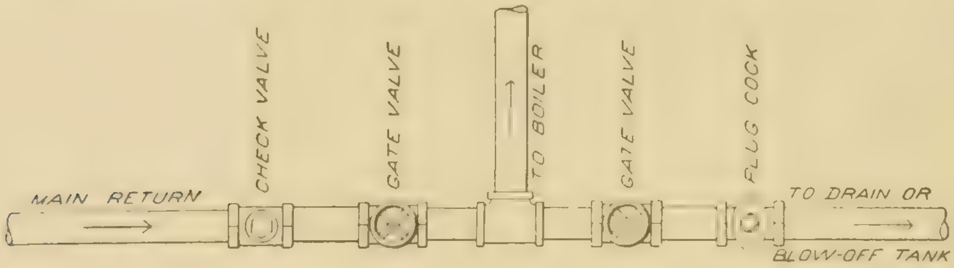


Fig. 48. A Good Arrangement of Return and Blow-Off Connections.

Table XXIII gives suitable sizes for return, blow-off, and feed pipes for boilers of different diameters.

TABLE XXIII

Sizes for Return, Blow-Off, and Feed Pipes

Diameter of Boiler	Size of Pipe for Gravity Return	Size of Blow-Off Pipe	Size of Feed Pipe
36 inches	1½ inches	1¼ inches	1 inch
42 "	2 "	1½ "	1 "
48 "	2 "	1½ "	1 "
54 "	2½ "	2 "	1¼ "
60 "	2½ "	2 "	1¼ "
66 "	3 "	2½ "	1½ "
72 "	3 "	2½ "	1½ "

Blow-Off Tank. Where the blow-off pipe connects with a sewer, some means must be provided for cooling the water, or the expansion and contraction caused by the hot water flowing through the drain-pipes will start the joints and cause leaks. For this reason it is customary to pass the water through a blow-off tank. A form of wrought-iron tank is shown in Fig. 49. It consists of a receiver supported on cast-iron cradles. The tank ordinarily stands nearly full of cold water.

The pipe from the boiler enters above the water-line, and the sewer connection leads from near the bottom, as shown. A vapor pipe is carried from the top of the tank above the roof of the building. When water from the boiler is blown into the tank, cold water from the bottom flows into the sewer, and the steam is carried off through the vapor pipe. The equalizing pipe is to prevent any siphon action which might draw the water out of the tank after a flow is once started. As only a part of the water is blown out of a boiler at one time, the blow-off tank can be of a comparatively small size. A tank 24 by 48 inches should be large enough for boilers up to 48 inches in diameter; and one 36 by 72 inches should care for a boiler 72 inches in diameter. If smaller quantities of water are blown off at one time, smaller tanks can be used. The sizes given above are sufficient for batteries of 2 or more boilers, as one boiler can be blown off and the water allowed to cool before a second one is blown off. Cast-iron tanks are often used in place of wrought-iron, and these may be sunk in the ground if desired.

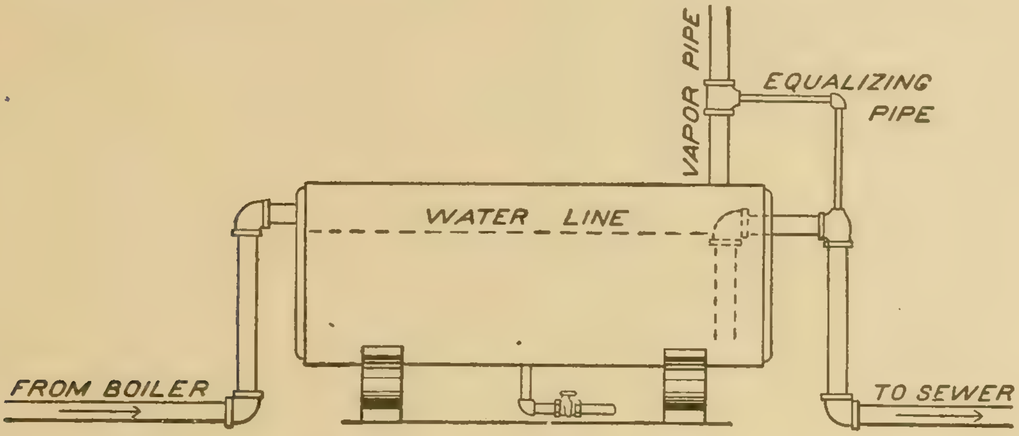
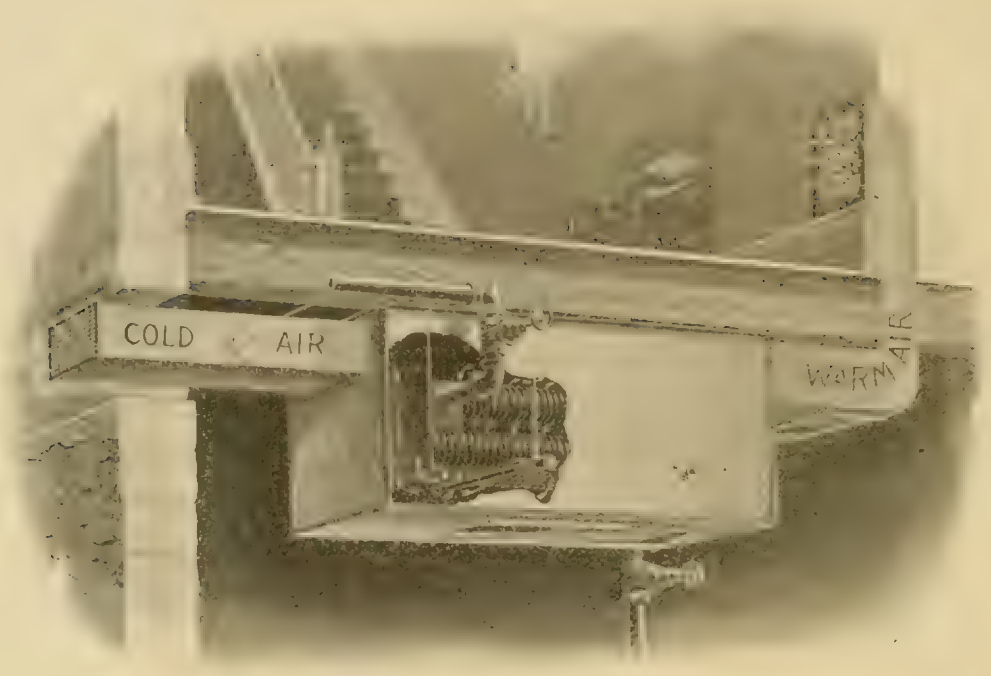


Fig. 49. Connections of Blow-Off Tank.



EXCELSIOR PATTERN RADIATOR USED IN THE INDIRECT METHOD OF WARMING
American Radiator Company

METHOD OF INDIRECT WARMING AND VENTILATION, SHOWING ROTARY CIRCULATION OF AIR
American Radiator Company

HEATING AND VENTILATION

PART II

INDIRECT STEAM HEATING

As already stated, in the indirect method of steam heating, a special form of heater is placed beneath the floor, and encased in galvanized iron or in brickwork. A cold-air box is connected with the space beneath the heater; and warm-air pipes at the top are connected with registers in the floors or walls as already described for furnaces. A separate heater may be provided for each register if the rooms are large, or two or more registers may be connected with the same heater if the horizontal runs of pipe are short. Fig. 50 shows a section through a heater arranged for introducing hot air into a room through a floor register; and Fig. 51 shows the same type of heater connected with a wall register. The cold-air box is seen at the bottom of the casing; and the air, in passing through the spaces between the sections of the heater, becomes warmed, and rises to the rooms above.

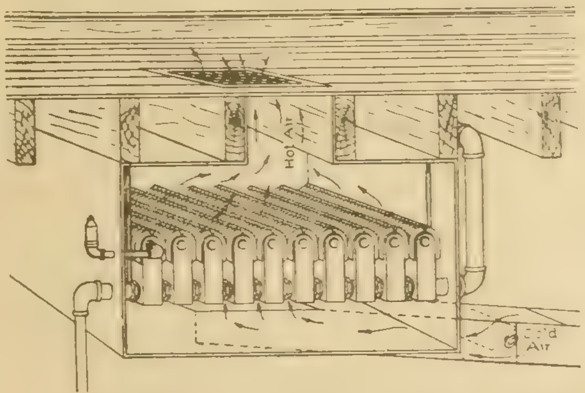


Fig. 50. Steam Heater Placed under Floor Register —Indirect System.

Different forms of indirect heaters are shown in Figs. 52 and 53. Several sections connected in a single group are called a *stack*. Sometimes the stacks are encased in brickwork built up from the basement floor, instead of in galvanized iron as shown in the cuts. This method of heating provides fresh air for ventilation, and for this reason is especially adapted for schoolhouses, hospitals, churches, etc. As compared with furnace heating, it has the advantage of being less affected by outside wind-pressure, as long runs of horizontal pipe are avoided and the heaters can be placed near the registers. In a large building where several furnaces would be required, a single boiler can be used, and the number of stacks increased to suit the existing conditions, thus making it necessary to run but a single fire. Another advantage is the large ratio between the heating and grate surface as compared with a furnace; and as a result, a large quantity of air is warmed to a moderate temperature, in place of a smaller quantity heated to a much higher temperature. This gives a more agreeable quality to the air, and renders it less dry. Direct and indirect systems are often combined, thus providing the living rooms with ventilation, while the hallways, corridors, etc., have only direct radiators for warming.

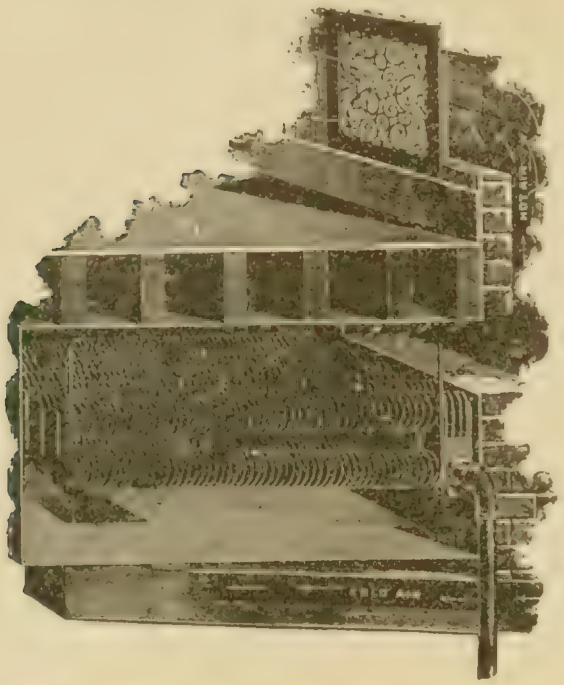


Fig. 51. Steam Heater Connected to Wall Register. Indirect System.

Types of Heaters. Various forms of indirect radiators are shown in Figs. 52, 53, 54, and 56. A hot-water radiator may be used for steam; but a steam radiator cannot always be used for hot water, as it must be especially designed to produce a continuous flow of water through it from top to bottom. Figs. 54 and 55 show the outside and the interior construction of a common pattern of indirect radiator

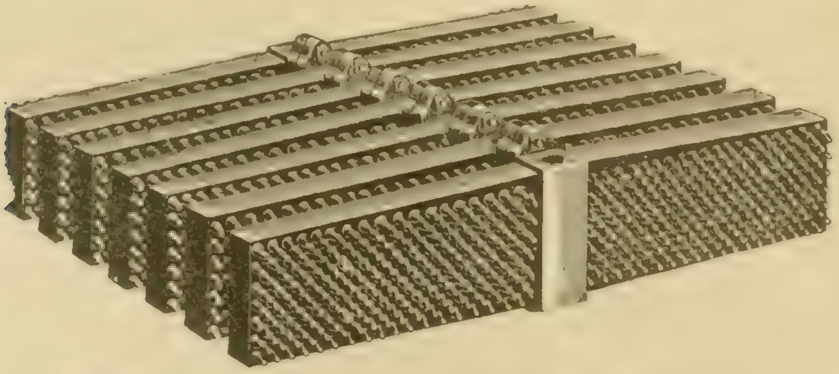


Fig. 52. One Form of Indirect Steam or Hot-Water Heater.

designed especially for steam. The arrows in Fig. 55 indicate the path of the steam through the radiator, which is supplied at the right, while the return connection is at the left. The air-valve in this case should be connected in the end of the last section near the return.

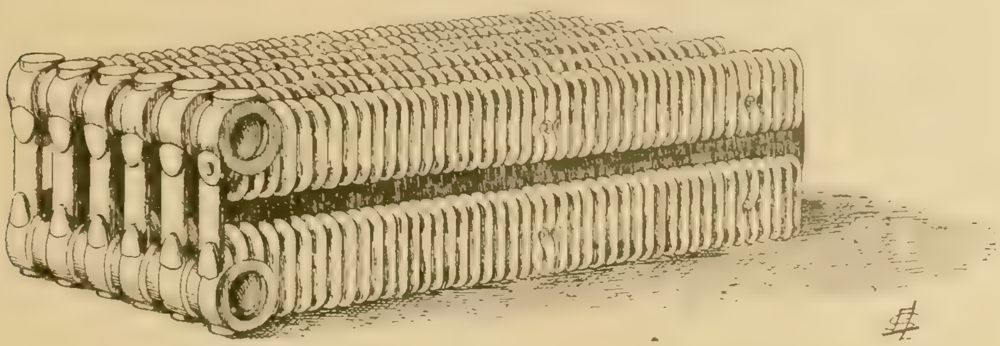


Fig. 53. Another Form of Indirect Steam or Hot-Water Heater.

A very efficient form of radiator, and one that is especially adapted to the warming of large volumes of air, as in schoolhouse work, is shown in Fig. 56, and is known as the *School pin* radiator. This can be used for either steam or hot water, as there is a continuous passage downward from the supply connection at the top to the return at the bottom. These sections or slabs are made up in stacks after the manner shown in Fig. 57, which represents an end view of several sections connected together with special nipples.

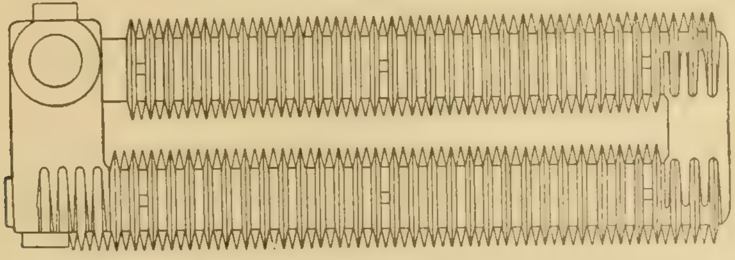


Fig. 54. Exterior View of a Common Type of Radiator for Indirect-Steam Heating.

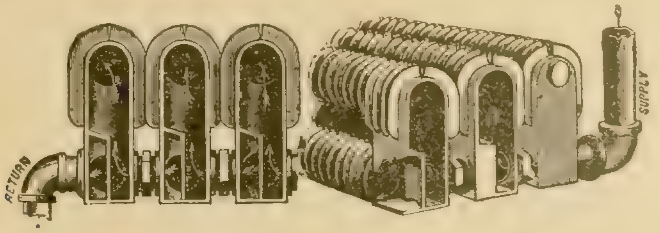


Fig. 55. Interior Mechanism of Radiator Shown in Fig. 54.

A very efficient form of indirect heater may be made up of wrought-iron pipe joined together with branch tees and return bends.

A heater like that shown in Fig. 58 is known as a *box coil.* Its efficiency is increased if the pipes are *staggered*—that is, if the pipes in alternate rows are placed over the spaces between those in the row below.

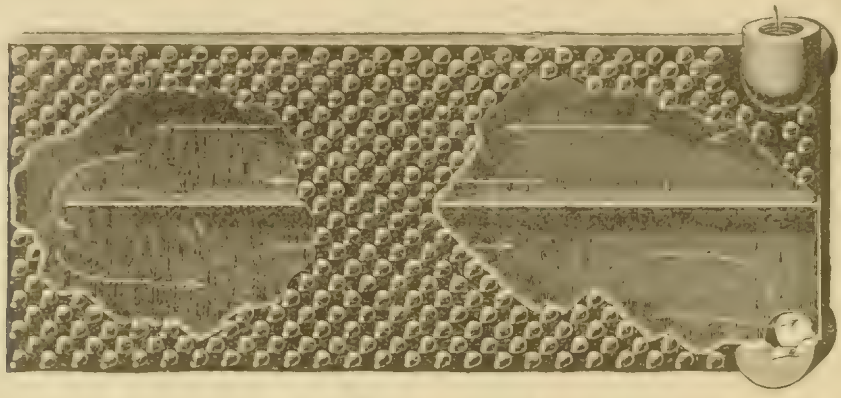


Fig. 56. "School Pin" Radiator. Especially Adapted for Warming Large Volumes of Air by Either Steam or Hot Water.

Efficiency of Heaters. The efficiency of an indirect heater depends upon its form, the difference in temperature between the steam and the surrounding air, and the velocity with which the air passes over the heater. Under ordinary conditions in dwelling-house work, a good form of indirect radiator will give off about 2 B. T. U. per square foot per hour for each degree difference in temperature between the steam and the entering air. Assuming a steam pressure of 2 pounds and an outside temperature of zero, we should have a difference in temperature of about 220 degrees, which, under the conditions stated, would give an efficiency of 220 × 2 = 440 B. T. U. per hour for each square foot of radiation. By making a similar computation for 10 degrees below zero, we find the efficiency to be 460. In the same manner we may calculate the efficiency for varying conditions of steam pressure and outside temperature. In the case of schoolhouses and similar buildings where large volumes of air are warmed to a moderate tem-

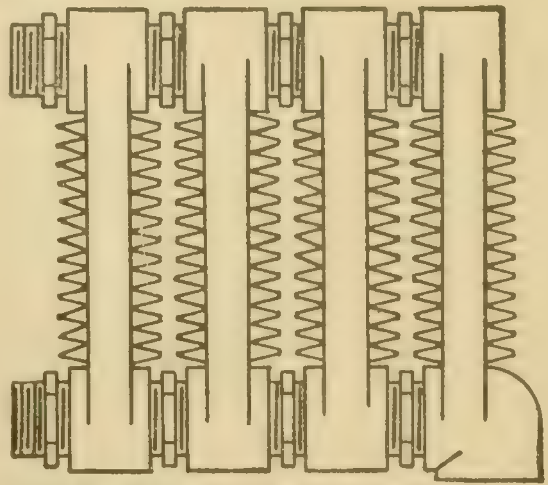


Fig. 57. End View of Several "School Pin" Radiator Sections Connected Together.

perature, a somewhat higher efficiency is obtained, owing to the increased velocity of the air over the heaters. Where efficiencies of 440 and 460 are used for dwellings, we may substitute 600 and 620 for schoolhouses. This corresponds approximately to 2.7 B. T. U. per square foot per hour for a difference of 1 degree between the air and steam.

The principles involved in indirect steam heating are similar to those already described in furnace heating. Part of the heat given off by the radiator must be used in warming up the air-supply to the temperature of the room, and part for offsetting the loss by conduction through walls and windows. The method of computing the heating surface required, depends upon the volume of air to be supplied to the room. In the case of a schoolroom or hall, where the air quantity is large as compared with the exposed wall and window surface, we should proceed as follows:

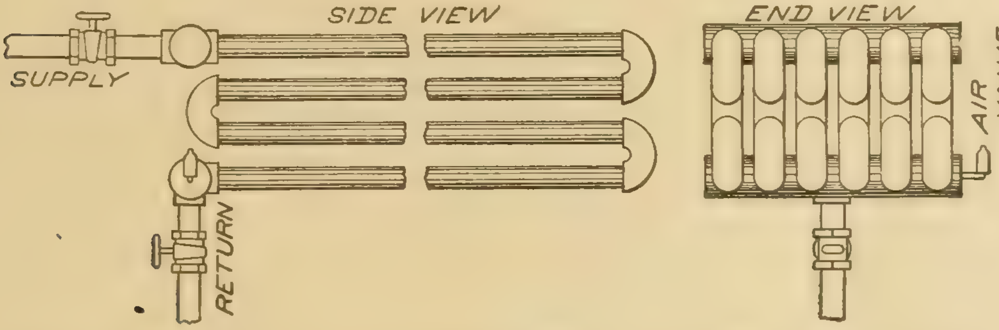


Fig. 58. "Box Coil," Built Up of Wrought-Iron Pipe, for Indirect-Steam Heating.

First compute the B. T. U. required for loss by conduction through walls and windows; and to this, add the B. T. U. required for the necessary ventilation; and divide the sum by the efficiency of the radiators. An example will make this clear.

Example. How many square feet of indirect radiation will be required to warm and ventilate a schoolroom in zero weather, where the heat loss by conduction through walls and windows is 36,000 B. T. U., and the air-supply is 100,000 cubic feet per hour?

By the methods given under "Heat for Ventilation," we have

$$\frac{100{,}000 \times 70}{55} \times 127{,}272 = \text{B. T. U. required for ventilation.}$$

$$36{,}000 + 127{,}272 = 163{,}272 \text{ B. T. U.} = \text{Total heat required.}$$

This in turn divided by 600 (the efficiency of indirect radiators under these conditions) gives 272 square feet of surface required.

In the case of a dwelling-house the conditions are somewhat changed, for a room having a comparatively large exposure will have perhaps only 2 or 3 occupants, so that, if the small air-quantity necessary in this case were used to convey the required amount of heat to the room, it would have to be raised to an excessively high temperature. It has been found by experience that the radiating surface necessary for indirect heating is about 50 per cent greater than that required for direct heating. So for this work we may compute the surface required for direct radiation, and multiply the result by 1.5.

Buildings like hospitals are in a class between dwellings and schoolhouses. The air-supply is based on the number of occupants, as in schools, but other conditions conform more nearly to dwelling-houses.

To obtain the radiating surface for buildings of this class, we compute the total heat required for warming and ventilation as in the case of schoolhouses, and divide the sum by the efficiencies given for dwellings—that is, 440 for zero weather, and 460 for 10 degrees below.

Example. A hospital ward requires 50,000 cubic feet of air per hour for ventilation; and the heat loss by conduction through walls, etc., is 100,000 B. T. U. per hour. How many square feet of indirect radiation will be required to warm the ward in zero weather?

50,000 × 70 ÷ 55 = 63,636 B. T. U. for ventilation; then,

$$\frac{63{,}636 + 100{,}000}{440} = 372 + \text{ square feet.}$$

EXAMPLES FOR PRACTICE

1. A schoolroom having 40 pupils is to be warmed and ventilated when it is 10 degrees below zero. If the heat loss by conduction is 30,000 B. T. U. per hour, and the air supply is to be 40 cubic feet per minute per pupil, how many square feet of indirect radiation will be required? Ans. 273.

2. A contagious ward in a hospital has 10 beds, requiring 6,000 cubic feet of air each, per hour. The heat loss by conduction in zero weather is 80,000 B. T. U. How many square feet of indirect radiation will be required? Ans. 355.

3. The heat loss from a sitting room is 11,250 B. T. U. per hour in zero weather. How many square feet of indirect radiation will be required to warm it? Ans. 75.

Stacks and Casings. It has already been stated that a group of sections connected together is called a stack, and examples of these with their casings are shown in Figs. 50 and 51. The casings are usually made of galvanized iron, and are made up in sections by means of small bolts so that they may be taken apart in case it is necessary to make repairs. Large stacks are often enclosed in brickwork, the sides consisting of 8-inch walls, and the top being covered over with a layer of brick and mortar supported on light wrought-iron tee-bars. Blocks of asbestos are sometimes used for covering, instead of brick, the whole being covered over with plastic material of the same kind.

Where a single stack supplies several flues or registers, the connections between these and the warm-air chamber are made in the same manner as already described for furnace heating. When galvanized-iron casings are used, the heater is supported by hangers from the floor above. Fig. 59 shows the method of hanging a heater from a wooden floor. If the floor is of fireproof construction, the hangers may pass up through the brickwork, and the ends be provided with nuts and large washers or plates; or they may be clamped to the iron beams which carry the floor. Where brick casings are used, the heaters are supported upon pieces of pipe or light I-beams built into the walls.

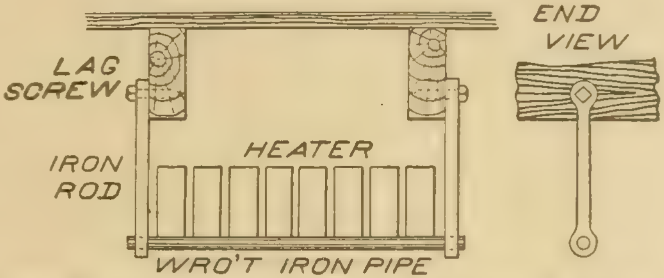


Fig. 59. Method of Hanging a Heater below a Wooden Floor.

The warm-air space above the heater should never be less than 8 inches, while 12 inches is preferable for heaters of large size. The cold-air space may be an inch or two less; but if there is plenty of room, it is good practice to make it the same as the space above.

Dampers. The general arrangement of a galvanized-iron casing and mixing damper is shown in Fig. 60. The cold-air duct is brought along the basement ceiling from the inlet window, and connects with the cold-air chamber beneath the heater. The entering air passes up between the sections, and rises through the register above, as shown by the arrows. When the mixing damper is in its lowest position, all air reaching the register must pass through the heater; but if the damper is raised to the position shown, part of the air will pass by without going through the heater, and the mixture entering through the register will be at a lower temperature than before. By changing the position of the damper, the proportions of warm and cold air delivered to the room can be varied, thus regulating the temperature without diminishing to any great extent the quantity of air delivered.

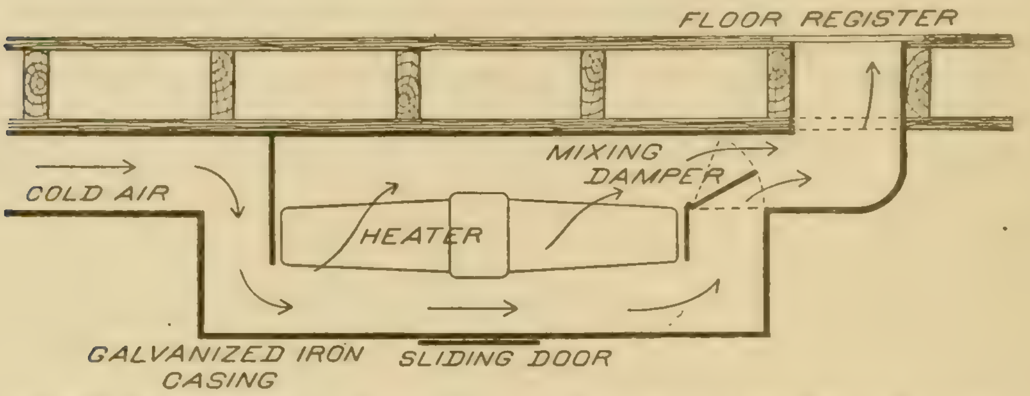


Fig. 60. General Arrangement of a Galvanized-Iron Casing and Mixing Damper. Damper between Heater and Register.

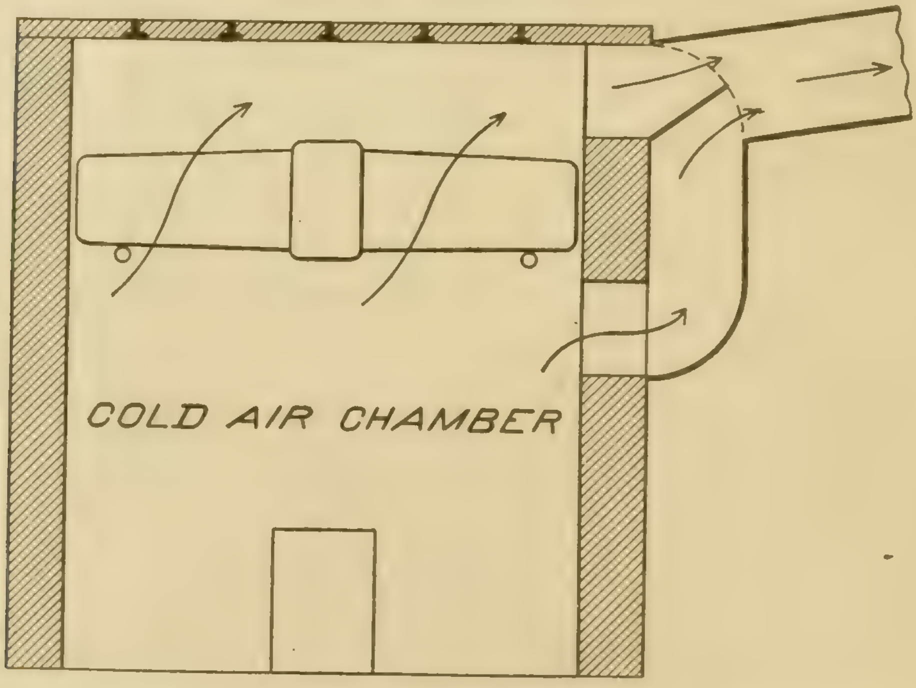


Fig. 61. Heater and Mixing Damper with Brick Casing. Damper between Heater and Register.

The objection to this form of damper is that there is a tendency for the air to enter the room before it is thoroughly mixed; that is, a stream of warm air will rise through one half of the register while cold air enters through the other. This is especially true if the connection between the damper and register is short. Fig. 61 shows a similar heater and mixing damper, with brick casing. Cold air is admitted to the large chamber below the heater, and rises through the sections to the register as before. The action of the mixing damper is the same as already described. Several flues or registers may be connected with a stack of this form, each connection having, in addition to its mixing damper, an adjusting damper for regulating the flow of air to the different rooms.

Another way of proportioning the air-flow in cases of this kind is to divide the hot-air chamber above the heater into sections, by means of galvanized-iron partitions, giving to each room its proper share of heating surface. If the cold-air supply is made sufficiently large, this arrangement is preferable to using adjusting dampers as described above. The partitions should be carried down the full depth of the heater between the sections, to secure the best results.

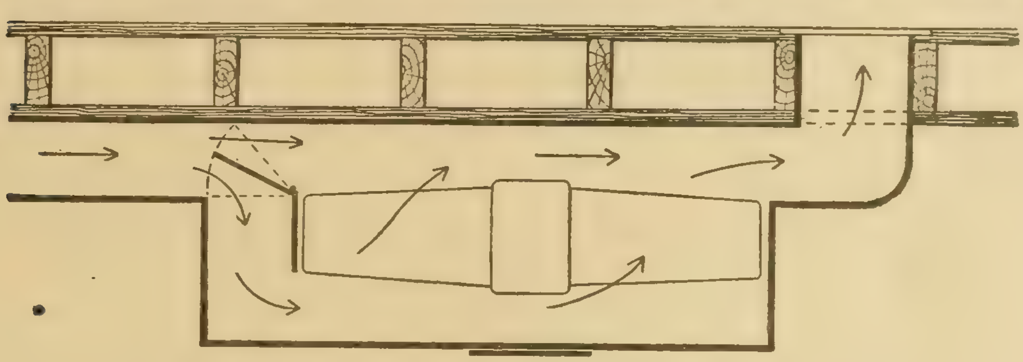


Fig. 62. Another Arrangement of Mixing Damper and Heater in Galvanized-Iron Casing. Heater between Damper and Register.

The arrangement shown in Fig. 62 is somewhat different, and overcomes the objection noted in connection with Fig. 60, by substituting another. The mixing damper in this case is placed at the other end of the heater. When it is in its highest position, all of the air must pass through the heater before reaching the register; but when partially lowered, a part of the air passes over the heater, and the result is a mixture of cold and warm air, in proportions depending upon the position of the damper. As the layer of warm air in this case is below the cold air, it tends to rise through it, and a more thorough mixture is obtained than is possible with the damper shown in Fig. 60. One quite serious objection, however, to this form of damper, is illustrated in Fig. 63. When the damper is nearly closed so that the greater part of the air enters above the heater, it has a tendency to fall between the sections, as shown by the arrows, and, becoming heated, rises again, so that it is impossible to deliver air to a room below a certain temperature. This peculiar action increases as the quantity of air admitted below the heater is diminished. When the inlet register is placed in the wall at some distance above the floor, as in schoolhouse work, a thorough mixture of air can be obtained by placing the heater so that the current of warm air will pass up the front of the flue and be discharged into the room through the lower part of the register. This is shown quite clearly in Fig. 64, where the current of warm air is represented by crooked arrows, and the cold air by straight arrows. The two currents pass up the flue separately; but as soon as they are discharged through the register the warm air tends to rise, and the cold air to fall, with the result of a more or less complete mixture, as shown.

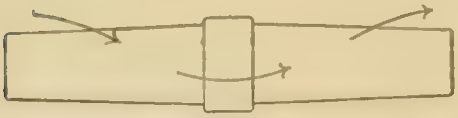


Fig. 63. Showing Difficulty of Regulating Temperature with Arrangement in Fig. 62.

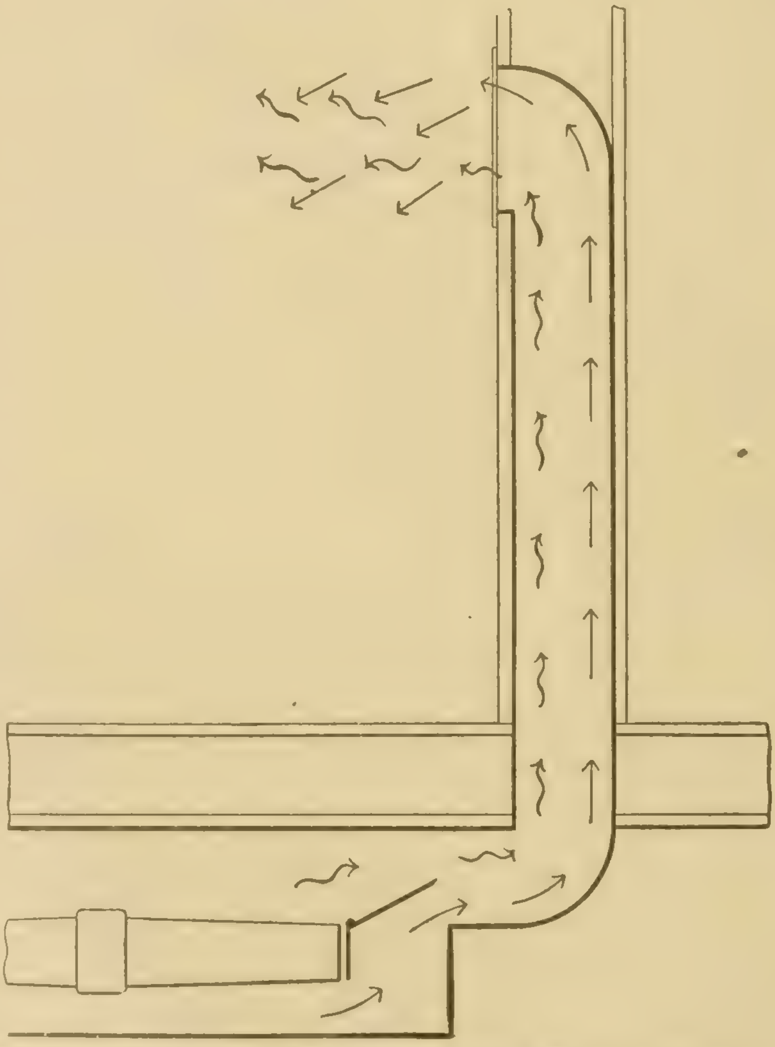
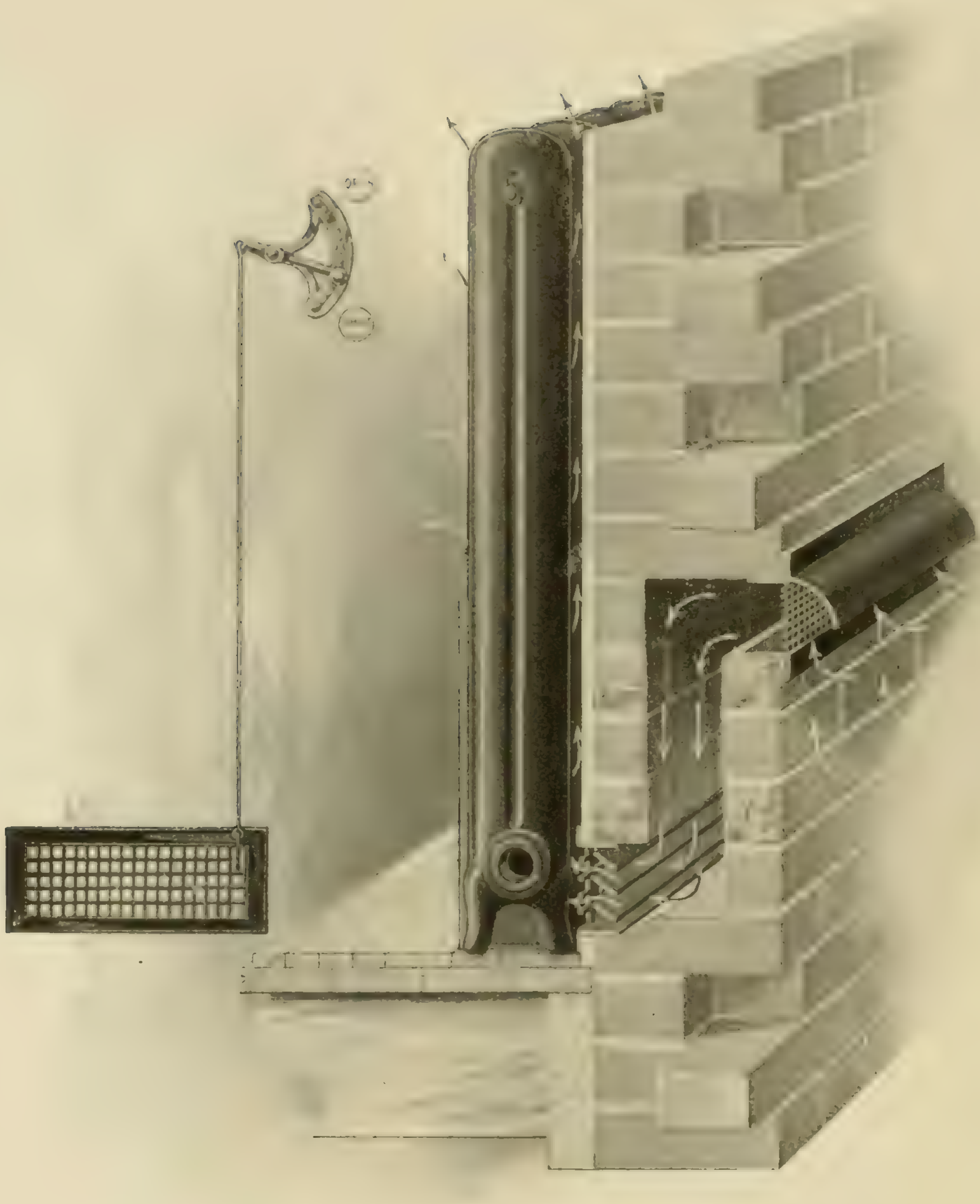
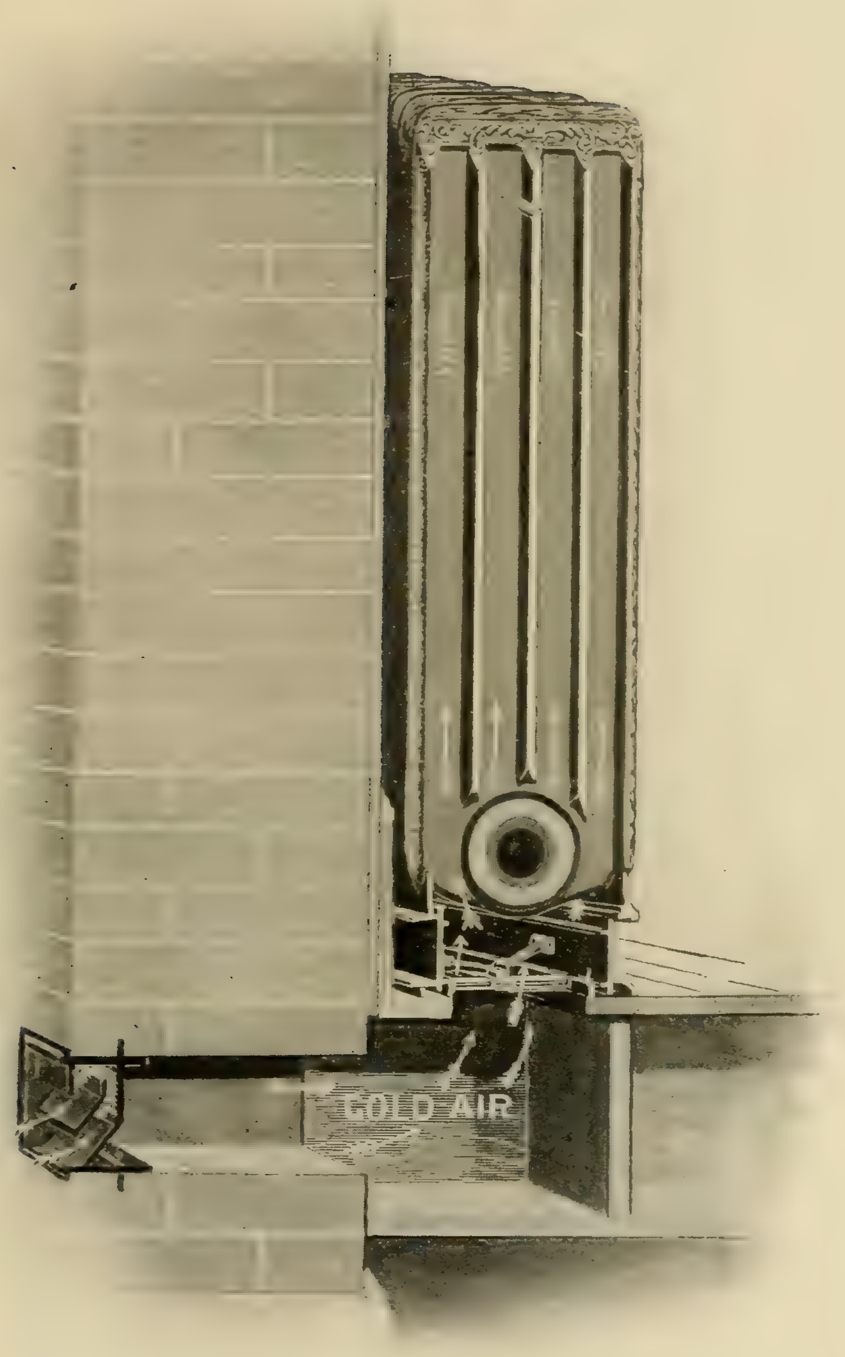


Fig. 64. Arrangement of Heater and Damper Causing Warm Air to Enter Room through Lower Part of Register, thus Securing Thorough Mixing



DIRECT-INDIRECT SYSTEM OF WARMING, SHOWING ADJUSTABLE DAMPER.
American Radiator Company.



DIRECT-INDIRECT METHOD OF WARMING TAKING A FRESH AIR SUPPLY FROM OUTSIDE AND PASSING IT UPWARD
American Radiator Company

It is often desirable to warm a room at times when ventilation is not necessary, as in the case of living rooms during the night, or for quick warming in the morning. A register and damper for air rotation should be provided in this case. Fig. 65 shows an arrangement for this purpose. When the damper is in the position shown, air will be taken from the room above and be warmed over and over; but, by raising the damper, the supply will be taken from outside. Special care should be taken to make all mixing dampers tight against air-leakage, else their advantages will be lost. They should work easily and close tightly against flanges covered with felt. They may be operated from the rooms above by means of chains passing over guide-pulleys; special attachments should be provided for holding in any desired position.

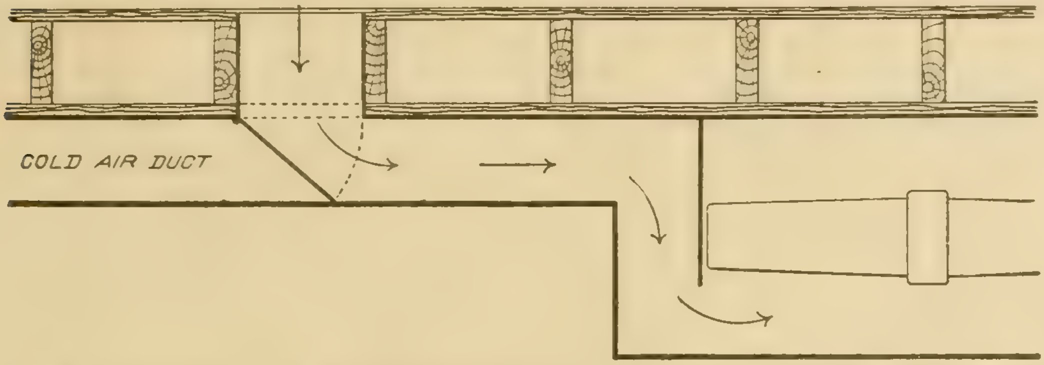


Fig. 65. Arrangement for Quick Heating without Ventilation. Damper Shuts off Fresh Air, and Air of Room Heated by Rotating Forth and Back through Register and Heater.

Warm-Air Flues. The required size of the warm-air flue between the heater and the register, depends first upon the difference in temperature between the air in the flue and that of the room, and second, upon the height of the flue. In dwelling-houses, where the conditions are practically constant, it is customary to allow 2 square inches area for each square foot of radiation when the room is on the first floor, and 1½ square inches for the second and third floors. In the case of hospitals, where a greater volume of air is required, these figures may be increased to 3 square inches for the first floor wards, and 2 square inches for those on the upper floors.

In schoolhouse work, it is more usual to calculate the size of flue from an assumed velocity of air-flow through it. This will vary greatly according to the outside temperature and the prevailing wind conditions. The following figures may be taken as average velocities obtained in practice, and may be used as a basis for calculating the required flue areas for the different stories of a school building:

1st floor, 280 feet per minute
2nd " , 340 " " "
3rd " , 400 " " "

These velocities will be increased somewhat in cold and windy weather and will be reduced when the atmosphere is mild and damp.

Having assumed these velocities, and knowing the number of cubic feet of air to be delivered to the room per minute, we have only to divide this quanity by the assumed velocity, to obtain the required flue area in square feet.

Example. A schoolroom on the second floor is to have an air-supply of 2,000 cubic feet per minute. What will be the required flue area?

ANS. 2000 ÷ 340 = 5.8 + sq. feet.

The velocities would be higher in the coldest weather, and dampers should be placed in the flues for throttling the air-supply when necessary.

Cold=Air Ducts. The cold-air ducts supplying heaters should be planned in a manner similar to that described for furnace heating. The air-inlet should be on the north or west side of the building; but this of course is not always possible. The method of having a large trunk line or duct with inlets on two or more sides of the building, should be carried out when possible. A cold-air room with large inlet windows, and ducts connecting with the heaters, makes a good arrangement for schoolhouse work. The inlet windows in this case should be provided with check-valves to prevent any outward flow of air. A detail of this arrangement is shown in Fig. 66.

This consists of a boxing around the window, extending from the floor to the ceiling. The front is sloped as shown, and is closed from the ceiling to a point below the bottom of the window. The remainder is open, and covered with a wire netting of about ½-inch mesh; to this are fastened flaps or checks of gossamer cloth about 6 inches in width. These are hemmed on both edges and a stout wire is run through the upper hem which is fastened to the netting by means of small copper or soft iron wire. The checks allow the air to flow inward but close when there is any tendency for the current to reverse.

The area of the cold-air duct for any heater should be about three-fourths the total area of the warm-air ducts leading from it.

If the duct is of any considerable length or contains sharp bends, it should be made the full size of all the warm-air ducts. Adjusting dampers should be placed in the supply duct to each separate stack. If a trunk with two inlets is used, each inlet should be of sufficient size to furnish the full amount of air required, and should be provided with cloth checks for preventing an outward flow of air, as already described. The inlet windows should be provided with some form of damper or slide, outside of which should be placed a wire grating, backed by a netting of about $\frac{3}{8}$-inch mesh.

Vent Flues. In dwelling-houses, vent flues are often omitted, and the frequent opening of doors and leakage are depended upon to carry away the impure air. A well-designed system of warming should provide some means for discharge ventilation, especially for bathrooms and toilet-rooms, and also for living rooms where lights are burned in the evening. Fireplaces are usually provided in the more important rooms of a well-built house, and these are made to serve as vent flues. In rooms having no fireplaces, special flues of tin or galvanized iron may be carried up in the partitions in the same manner as the warm-air flues. These should be gathered together in the attic, and connected with a brick flue running up beside the boiler or range chimney.

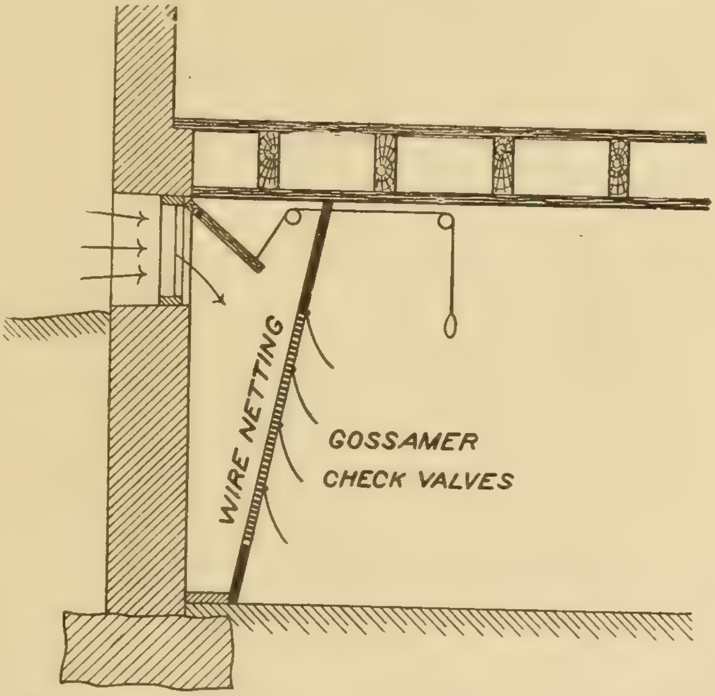


Fig. 66. Air-Inlet Provided with Check-Valves to Prevent Outward Flow of Air.

Very fair results may be obtained by simply letting the flues open into an unfinished attic, and depending upon leakage through the roof to carry away the foul air.

The sizes of flues may be made the reverse of the warm-air flues that is, $1\frac{1}{2}$ square inches area per square foot of indirect radiation for rooms on the first floor, and 2 square inches for those on the second. This is because the velocity of flow will depend upon the height of flue, and will therefore be greater from the first floor. The flow of air through the vents will be slow at best, unless some means is provided for warming the air in the flue to a temperature above that of the room with which it connects.

The method of carrying up the outboard discharge beside a warm chimney is usually sufficient in dwelling-houses; but when it is desired to move larger quantities of air, a loop of steam pipe should be run inside the flue. This should be connected for drainage and air-venting as shown in Fig. 67. When vents are carried through the roof independently, some form of protecting hood should be provided for keeping out the snow and rain. A simple form is shown in Fig. 68. Flues carried outboard in this way should always be extended well above the ridges of adjacent roofs to prevent down drafts in windy weather.

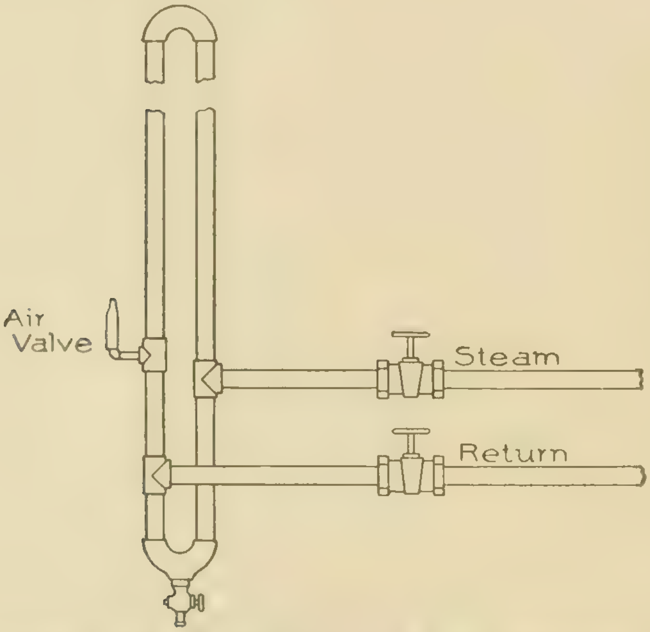


Fig. 67. Loop of Steam Pipe to be Run Inside Flue. Connected for Drainage and Air-Venting.

For schoolhouse work we may assume average velocities through the vent flues, as follows:

1st floor, 340 feet per minute.
2nd " , 280 " " "
3rd " , 220 " " "

Where flue sizes are based on these velocities, it is well to guard against down drafts by placing an aspirating coil in the flue. A single row of pipes across the flue as shown in Fig. 69, is usually sufficient for this purpose when the flues are large and straight;

otherwise, two rows should be provided. The slant height of the heater should be about twice the depth of the flue, so that the area between the pipes shall equal the free area of the flue.

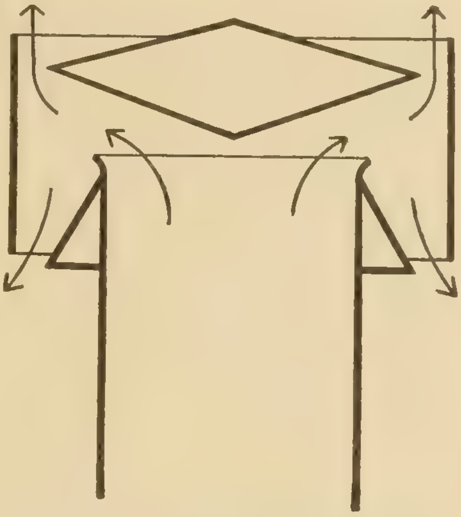


Fig. 68. Section Showing Simple Form of Protecting Hood for Vent Carried through Roof.

Large vent flues of this kind should always be provided with dampers for closing at night, and for regulation during strong winds.

Sometimes it is desired to move a given quantity of air through a flue which is already in place. Table XXIV shows what velocities may be obtained through flues of different heights, for varying differences in temperature between the outside air and that in the flue.

Example.—It is desired to discharge 1,300 cubic feet of air per minute through a flue having an area of 4 square feet and a height of 30 feet. If the efficiency of an aspirating coil is 400 B. T. U., how many square feet of surface will be required to move this amount of air when the temperature of the room is 70° and the outside temperature is 60°?

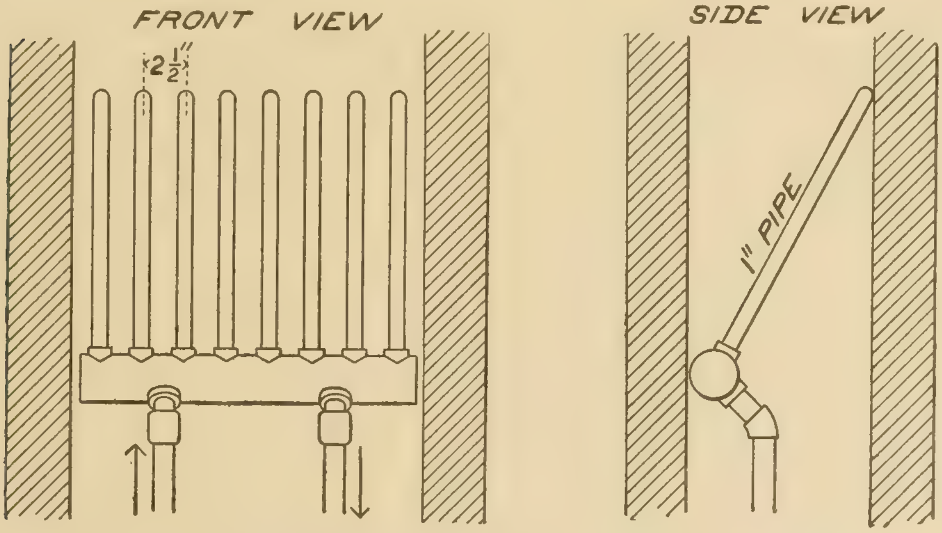


Fig. 69. Aspirating Coil Placed in Flue to Prevent Down Drafts.

1,300 ÷ 4 = 325 feet per minute = Velocity through the flue. Looking in Table XXIV, and following along the line opposite a 30-foot flue, we find that to obtain this velocity there must be a difference of 30 degrees between the air in the flue and the external air.

If the outside temperature is 60 degrees, then the air in the flue must be raised to 60 + 30 = 90 degrees. The air of the room being at 70 degrees, a rise of 20 degrees is necessary. So the problem resolves itself into the following: What amount of heating surface having an efficiency of 400 B. T. U. is necessary to raise 1,300 cubic feet of air per minute through 20 degrees?

TABLE XXIV

Air-Flow through Flues of Various Heights under Varying Conditions of Temperature

(Volumes given in cubic feet per square foot of sectional area of flue)

Height of Flue in Feet	Excess of Temperature of Air in Flue Above that of External Air					
	5°	10°	15°	20°	30°	50°
5	55	76	94	109	134	167
10	77	108	133	153	188	242
15	94	133	162	188	230	297
20	108	153	188	217	265	342
25	121	171	210	242	297	383
30	133	188	230	265	325	419
35	143	203	248	286	351	453
40	153	217	265	306	375	484
45	162	230	282	325	398	514
50	171	242	297	342	419	541
60	188	264	325	373	461	594

1,300 cubic feet per minute = 1,300 × 60 = 78,000 per hour; and making use of our formula for "heat for ventilation," we have

$$\frac{78{,}000 \times 20}{55} = 28{,}363 \text{ B. T. U.};$$

and this divided by 400 = 71 square feet of heating surface required.

EXAMPLES FOR PRACTICE

1. A schoolroom on the third floor has 50 pupils, who are to be furnished with 30 cubic feet of air per minute each. What will be the required areas in square feet of the supply and vent flues?
Ans. Supply, 3.7 +. Vent, 6.8 +.

2. What size of heater will be required in a vent flue 40 feet high and with an area of 5 square feet, to enable it to discharge 1,530 cubic feet per minute, when the outside temperature is 60°? (Assume an efficiency of 400 B. T. U. for the heater.) Ans. 41.7 square feet.

Registers. Registers are made of cast iron and bronze, in a great variety of sizes and patterns. The almost universal finish for cast-iron registers is black "Japan;" but they are also finished in colors and electroplated with copper and nickel. Fig. 70 shows a section through a floor register, in which *A* represents the valves, which may be turned in a vertical or horizontal position, thus opening or closing the register; *B* is the iron border; *C*, the register box of tin or galvanized iron; and *D*, the warm-air pipe. Floor registers are usually set in cast-iron borders, one of which is shown in Fig. 71; while wall registers may be screwed directly to wooden borders or frames to correspond with the finish of the room. Wall registers should be provided with pull-cords for opening and closing from the floor; these are shown in Fig. 72. The plain lattice pattern shown in Fig. 73 is the best for schoolhouse work, as it has a comparatively free opening for air-flow and is pleasing and simple in design. More elaborate patterns are used for fine dwelling-house work. Registers with shut-off valves are used for air-inlets, while the plain register faces without the valves are placed in the vent openings. The vent flues are usually gathered together in the attic, and a single damper may be used to shut off the whole number at once. Flat or round wire gratings of open pattern are often used in place of

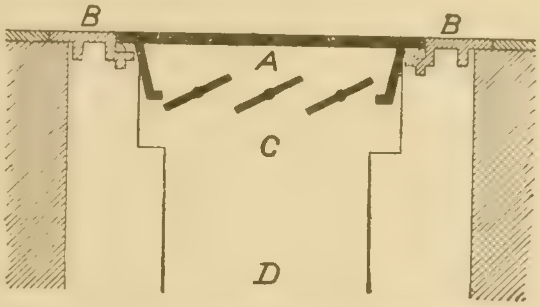


Fig. 70. Section through a Floor Register.

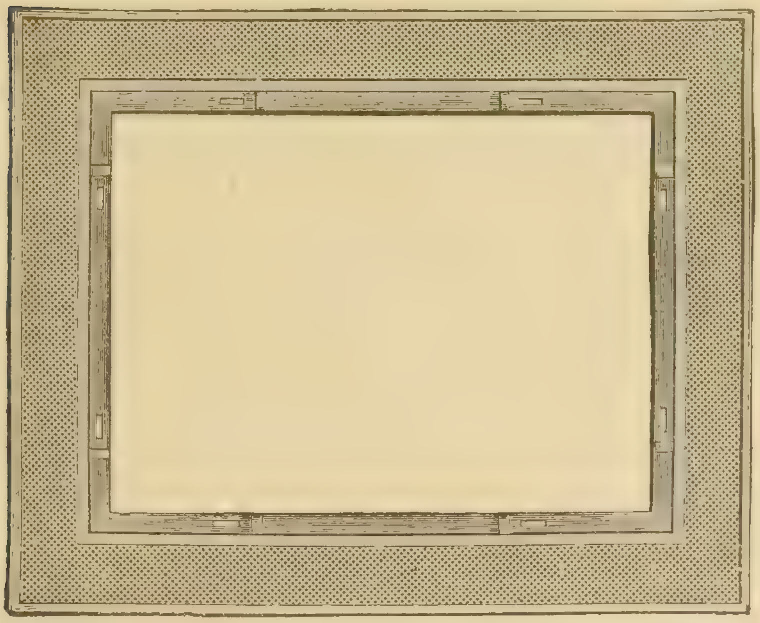


Fig. 71. Cast-Iron Border for a Floor Register.

register faces. The grill or solid part of a register face usually takes up about $\frac{1}{3}$ of the area; hence in computing the size, we must allow for this by multiplying the required "net area" by 1.5, to obtain the "total" or "over-all" area.

Example. Suppose we have a flue 10 inches in width and wish to use a register having a free area of 200 square inches. What will be the required height of the register?

$200 \times 1.5 = 300$ square inches, which is the total area required; then $300 \div 10 = 30$, which is the required height, and we should use a 10 by 30-inch register. When a register is spoken of as a 10 by 30-inch or a 10 by 20-inch, etc., the dimensions of the latticed opening are meant, and not the outside dimensions of the whole register. The free opening should have the same area as the flue with which it connects. In designing new work, one should provide himself with a trade catalogue, and use only standard sizes, as special patterns and sizes are costly. Fig. 74 shows the method of placing gossamer check-valves back of the vent register faces to prevent down drafts, the same as described for fresh-air inlets.

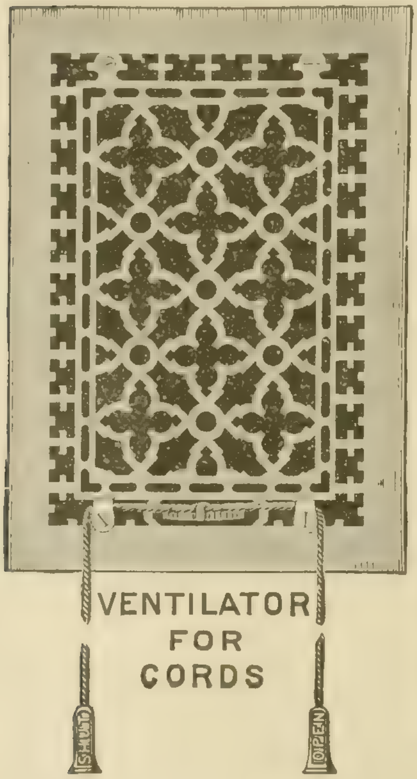


Fig. 72. Wall Register with Pull Cords for Opening and Closing.

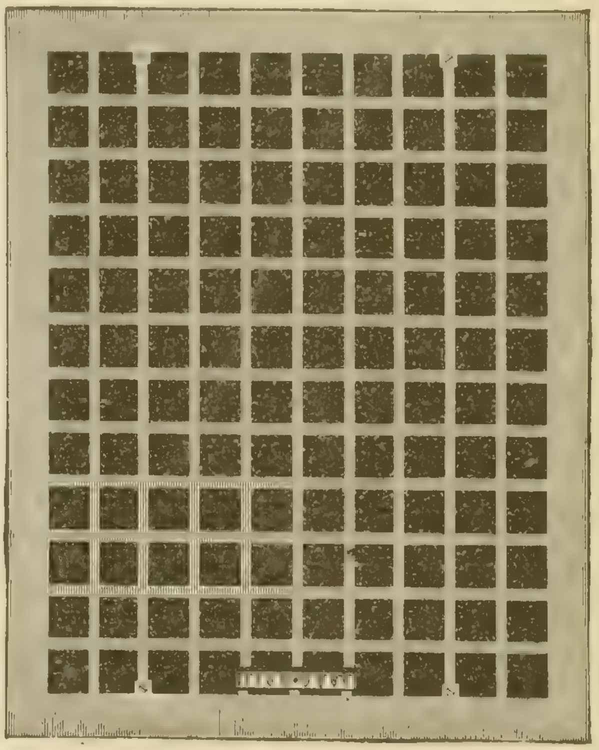


Fig. 73. Plain Lattice Pattern Register. Best for Schoolhouse Work.

Inlet registers in dwelling-house and similar work are placed either in the floor or in the baseboard; sometimes they are located under the windows, just above the baseboard. The object in view is to place them where the currents of air entering the room will not be objectionable to persons sitting near windows. A long, narrow floor-register placed close to the wall in front of a window, sends up a shallow current of warm air, which is not especially noticeable to one sitting near it. Inlet registers are preferably placed near outside walls, especially in large rooms. Vent registers should be placed in inside walls, near the floor.

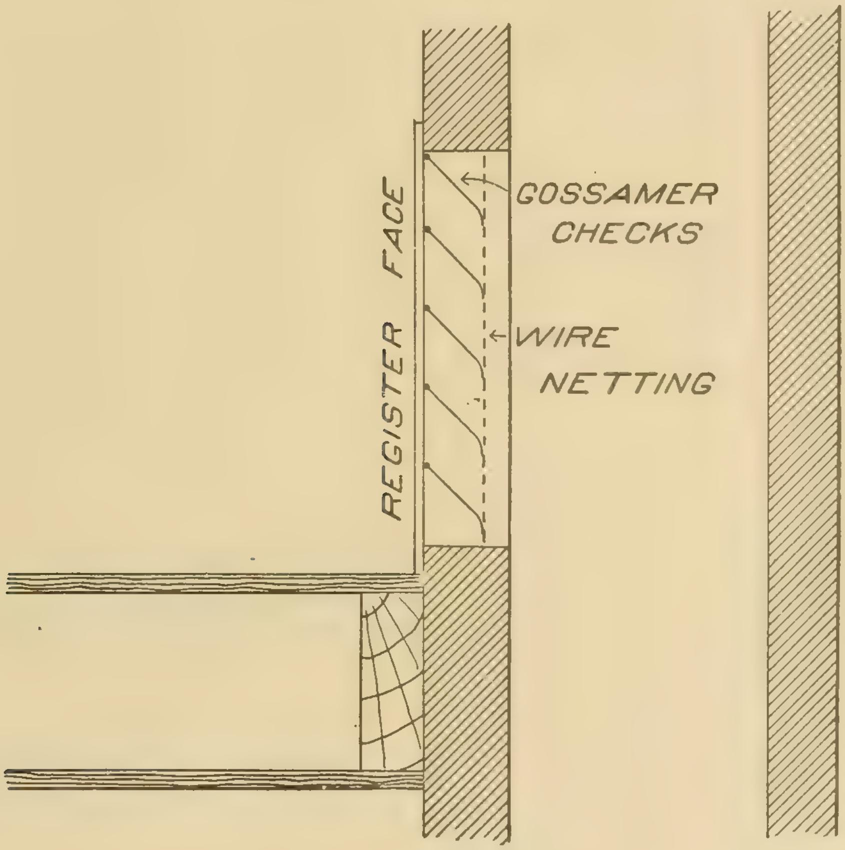


Fig. 74. Method of Placing Gossamer Check-Valves back of Vent Register Face to Prevent Down Drafts.

Pipe Connections. The two-pipe system with dry or sealed returns is used in indirect heating. The conditions to be met are practically the same as in direct heating, the only difference being that the radiators are at the basement ceiling instead of on the floors above. The exact method of making the pipe connections will depend somewhat upon existing conditions; but the general method shown in Fig. 75 may be used as a guide, with modifications to suit any special case. The ends of all supply mains should be dripped, and the horizontal returns should be sealed if possible.

Pipe Sizes. The tables already given for the proportioning of pipe sizes can be used for indirect systems. The following table has been computed for an efficiency of 640 B. T. U. per square foot of surface per hour, which corresponds to a condensation of $\frac{2}{3}$ of a pound of steam. This is twice that allowed for direct radiation in Table XVII; so that we can consider 1 square foot of indirect surface as equal to 2 of direct in computing pipe sizes.

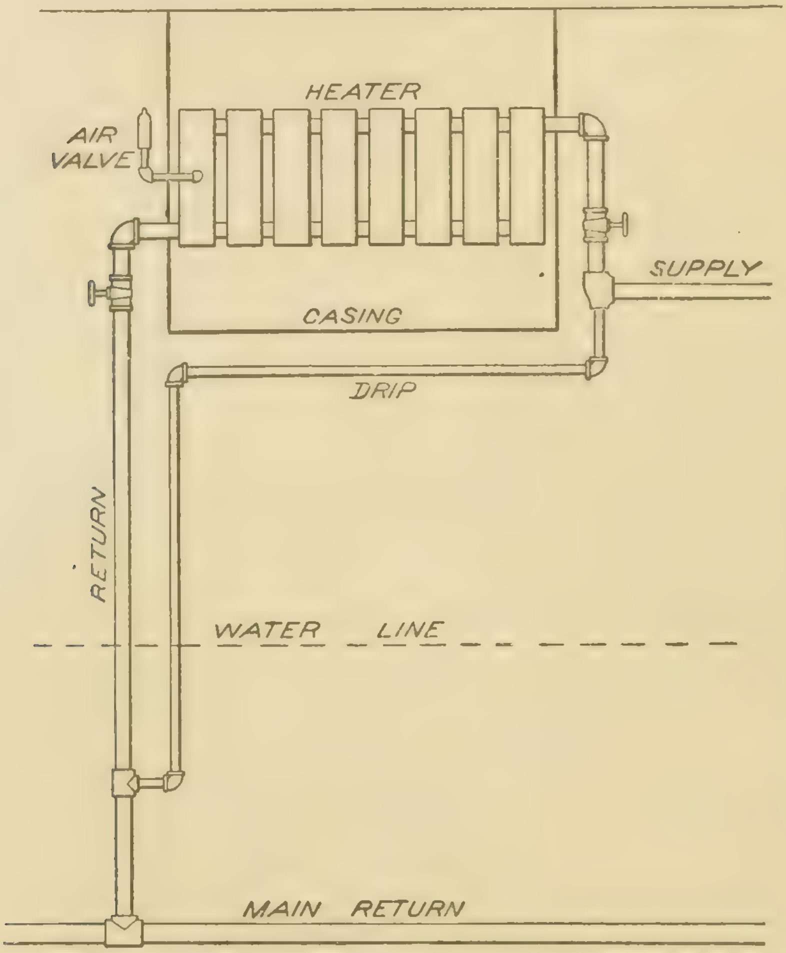


Fig. 75. General Method of Making Pipe and Radiator Connections in Basement, in Indirect Heating.

As the indirect heaters are placed in the basement, care must be taken that the bottom of the radiator does not come too near the water-line of the boiler, or the condensation will not flow back properly; this distance, under ordinary conditions, should not be less than 2 feet. If much less than this, the pipes should be made extra large, so that there may be little or no drop in pressure between the boiler

TABLE XXV

Indirect Radiating Surface Supplied by Pipes of Various Sizes

Size of Pipe	Square Feet of Indirect Radiation which will be Supplied with		
	¼ Pound Drop in 200 Feet	¼ Pound Drop in 100 Feet	½ Pound Drop in 100 Feet
1 in.	28	40	57
1¼ "	51	72	105
1½ "	67	95	170
2 "	185	262	375
2½ "	335	475	675
3 "	540	775	1,105
3½ "	812	1,160	1,645
4 "	1,140	1,625	2,310
5 "	2,030	2,900	4,110
6 "	3,260	4,660	6,600
7 "	4,830	6,900	9,810
8 "	6,800	9,720	13,860

and the heater. A drop in pressure of 1 pound would raise the water-line at the heater 2.4 feet.

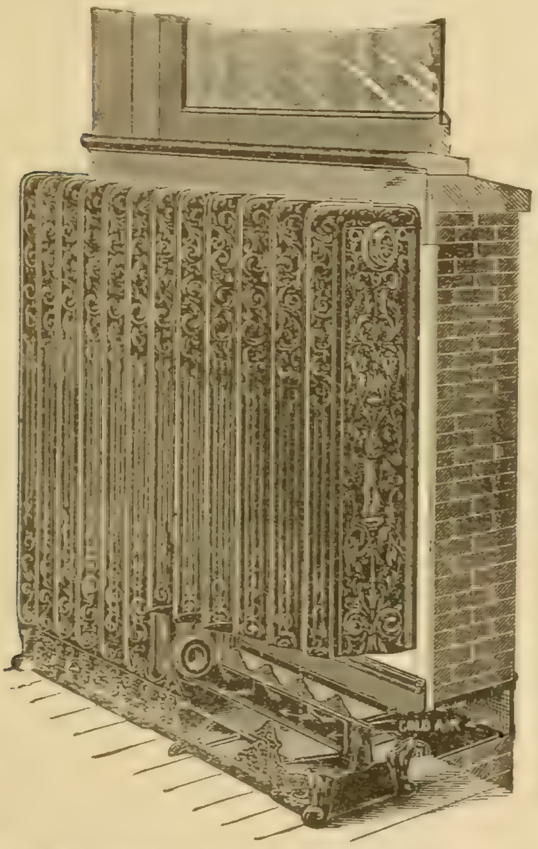


Fig. 76. General Form of Direct-Indirect Radiator.

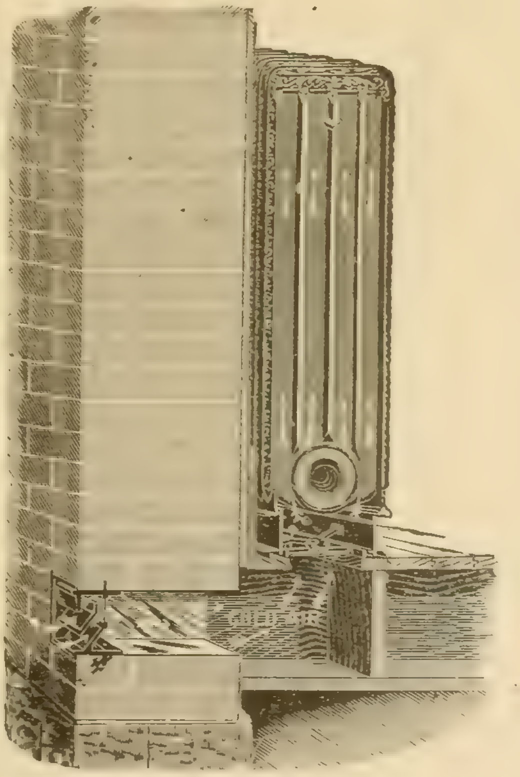


Fig. 77. Section through Radiator Shown in Fig. 76.

Direct-Indirect Radiators. A direct-indirect radiator is similar in form to a direct radiator, and is placed in a room in the same manner. Fig. 76 shows the general form of this type of radiator; and Fig. 77 shows a section through the same. The shape of the sections is such, that when in place, small flues are formed between them. Air is admitted through an opening in the outside wall; and, in passing upward through these flues, becomes heated before entering the room. A switch-damper is placed in the duct at the base of the radiator, so that the air may be taken from the room itself instead of from out of doors, if so desired. This is shown more particularly in Fig. 76.

Fig. 78 shows the wall box provided with louvre slats and netting, through which the air is drawn. A damper door is placed at either end of the radiator base; and, if desired, when the cold-air supply is shut off by means of the register in the air-duct, the radiator can be converted into the ordinary type by opening both damper doors, thus taking the air from the room instead of from the outside. It is customary to increase the size of a direct-indirect radiator 30 per cent above that called for in the case of direct heating.

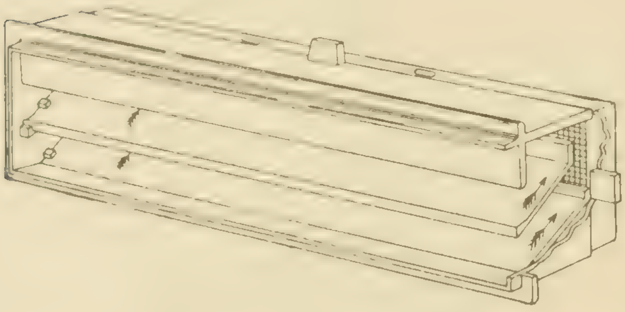


Fig. 78. Wall Box with Louvre Slats and Netting. Direct Indirect System.

CARE AND MANAGEMENT OF STEAM-HEATING BOILERS

Special directions are usually supplied by the maker for each kind of boiler, or for those which are to be managed in any peculiar way. The following general directions apply to all makes, and may be used regardless of the type of boiler employed:

Before starting the fire, see that the boiler contains sufficient water. The water-line should be at about the center of the gauge-glass.

The smoke-pipe and chimney flue should be clean, and the draft good.

Build the fire in the usual way, using a quality of coal which is best adapted to the heater. In operating the fire, keep the firepot full of coal, and shake down and remove all ashes and cinders as often as the state of the fire requires it.

Hot ashes or cinders must not be allowed to remain in the ashpit under the grate-bars, but must be removed at regular intervals to prevent burning out the grate.

To control the fire, see that the damper regulator is properly attached to the draft doors and the damper; then regulate the draft by weighting the automatic lever as may be required to obtain the necessary steam pressure for warming. Should the water in the boiler escape by means of a broken gauge-glass, or from any other cause, the fire should be dumped, and the boiler allowed to cool before adding cold water.

An empty boiler should never be filled when hot. If the water gets low at any time, but still shows in the gauge-glass, more water should be added by the means provided for this purpose.

The safety-valve should be lifted occasionally to see that it is in working order.

If the boiler is used in connection with a gravity system, it should be cleaned each year by filling with pure water and emptying through the blow-off. If it should become foul or dirty, it can be thoroughly cleansed by adding a few pounds of caustic soda, and allowing it to stand for a day, and then emptying and thoroughly rinsing.

During the summer months, it is recommended that the water be drawn off from the system, and that air-valves and safety-valves be opened to permit the heater to dry out and to remain so. Good results, however, are obtained by filling the heater full of water, driving off the air by boiling slowly, and allowing it to remain in this condition until needed in the fall. The water should then be drawn off and fresh water added.

The heating surface of the boiler should be kept clean and free from ashes and soot by means of a brush made especially for this purpose.

Should any of the rooms fail to heat, examine the steam valves in the radiators. If a two-pipe system, both valves at each radiator must be opened or closed at the same time, as required. See that the air-valves are in working condition.

If the building is to be unoccupied in cold weather, draw all the water out of the system by opening the blow-off pipe at the boiler and all steam valves and air-valves at the radiators.

HOT-WATER HEATERS

Types. Hot-water heaters differ from steam boilers principally in the omission of the reservoir or space for steam above the heating surface. The steam boiler might answer as a heater for hot water; but the large capacity left for the steam would tend to make its operation slow and rather unsatisfactory, although the same type of boiler is sometimes used for both steam and hot water. The passages in a hot-water heater need not extend so directly from bottom to top as in a steam boiler, since the problem of providing for the free liberation of the steam bubbles does not have to be considered. In general, the heat from the furnace should strike the surfaces in such a manner as to increase the natural circulation; this may be accomplished to a certain extent by arranging the heating surface so that a large proportion of the direct heat will be absorbed near the top of the heater. Practically the boilers for low-pressure steam and for hot water differ from each other very little as to the character of the heating surface, so that the methods already given for computing the size of grate surface, horse-power, etc., under the head of "Steam Boilers," can be

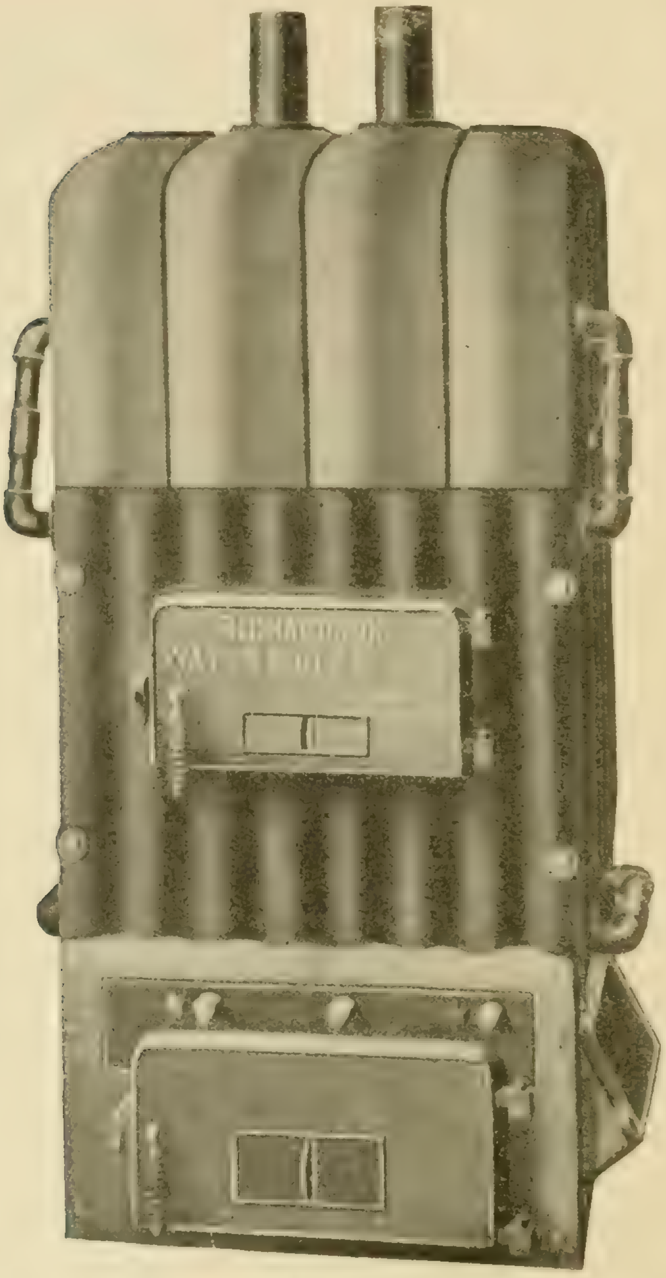


Fig. 79. Richardson Sectional Hot-Water Heater.

used with satisfactory results in the case of hot-water heaters.

It is sometimes stated that, owing to the greater difference in temperature between the furnace gases and the water in a hot-water heater, as compared with steam, the heating surface will be more efficient and a smaller heater can be used. While this is true to a certain extent, different authorities agree that this advantage is so small that no account should be taken of it, and the general proportions of the heater should be calculated in the same manner as for steam. Fig. 79 shows a form of hot-water heater made up of slabs or sections similar to the sectional steam boiler shown in Part I. The size can be increased in a similar manner, by adding more sections. In this case, however, the boiler is increased in width instead of in length. This has an advantage in the larger sizes, as a second fire door can be added, and all parts of the grate can be reached as well in the large sizes as in the small.

Fig. 80 shows a different form of sectional boiler, in which the sections are placed one above another. These boilers are circular in form and well adapted to dwelling-houses and similar work.

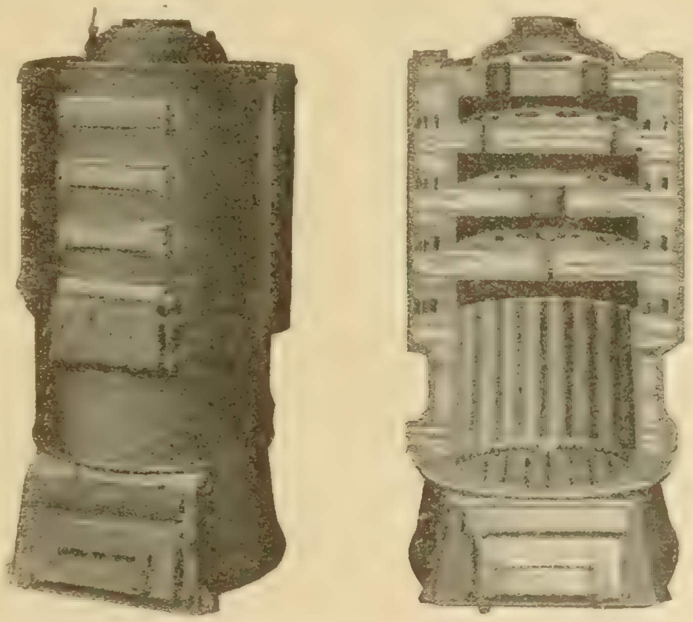


Fig. 80. "Invincible" Boiler, with Sections Superposed.
Courtesy of American Radiator Co.

Fig. 81 shows another type of cast-iron heater which is not made in sections. The space between the outer and inner shells surrounding the furnace is filled with water, and also the cross-pipes directly over the fire and the drum at the top. The supply to the radiators is taken off from the top of the heater, and the return connects at the lowest point.

The ordinary horizontal and vertical tubular boilers, with various modifications, are used to a considerable extent for hot-water heating, and are well adapted to this class of work, especially in the case of large buildings.

Automatic regulators are often used for the purpose of maintaining a constant temperature of the water. They are constructed in different ways—some depend upon the expansion of a metal pipe or rod at different temperatures, and others upon the vaporization and consequent pressure of certain volatile liquids. These means are usually employed to open small valves which admit water-pressure under rubber diaphragms; and these in turn are connected by means of chains with the draft doors of the furnace, and so regulate the draft as required to maintain an even temperature of the water in the heater. Fig. 82 shows one of the first kind. *A* is a metal rod placed in the flow pipe from the heater, and is so connected with the valve *B* that when the water reaches a certain temperature the expansion of the rod opens the valve and admits water from the street pressure through the pipes *C* and *D* into the chamber *E*. The bottom of *E* consists of a rubber diaphragm, which is forced down by the water-pressure and carries with it the lever which operates the dampers as shown, and checks the fire. When the temperature of the water drops, the rod contracts and valve *B* closes, shutting off the pressure from the chamber *E*. A spring is provided to throw the lever back to its original position,

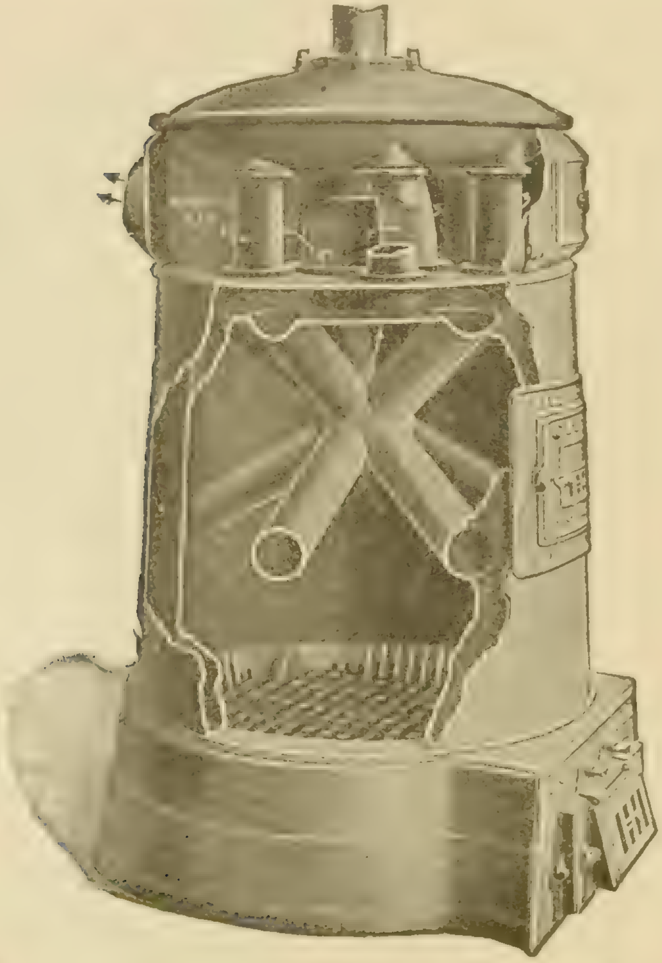
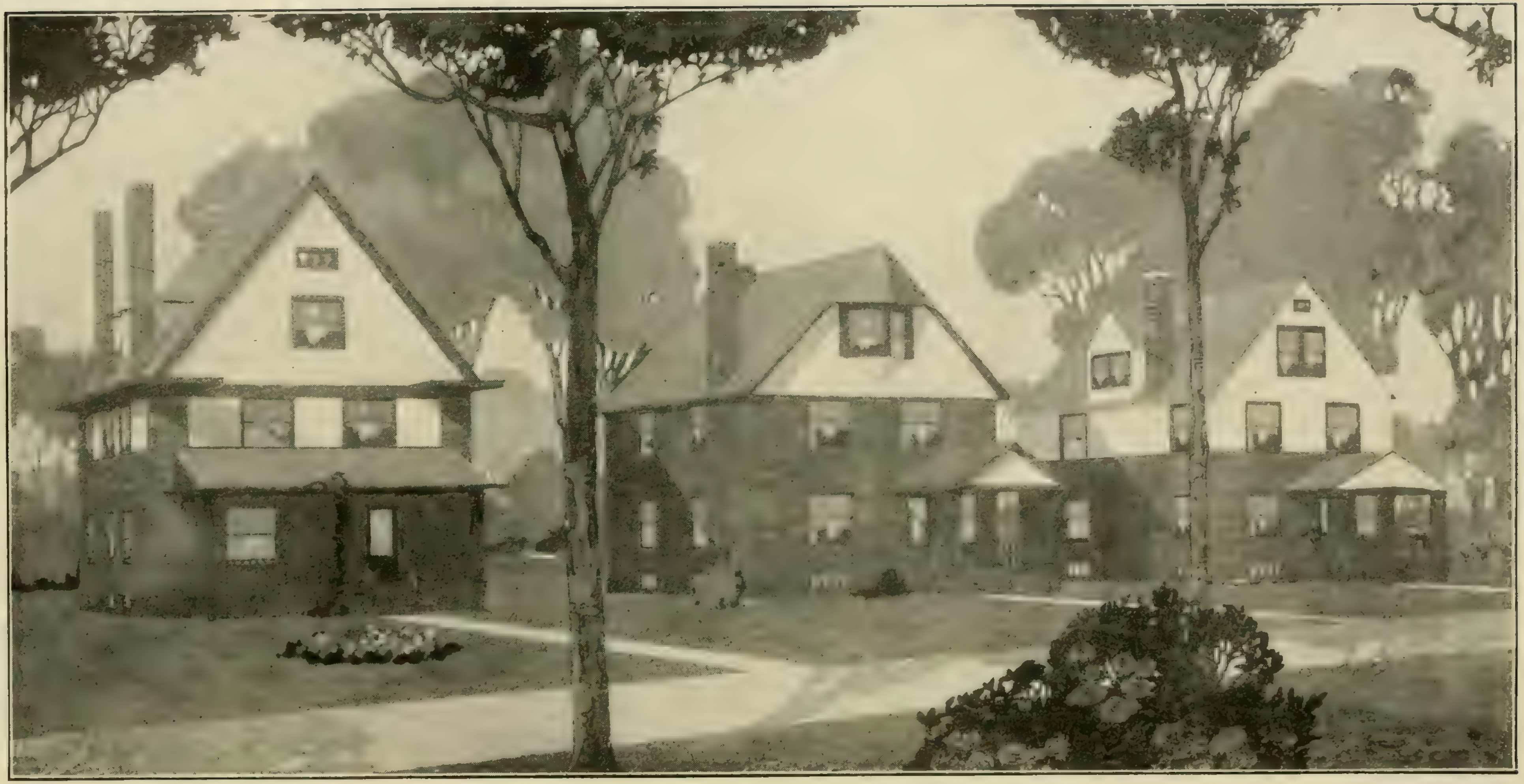
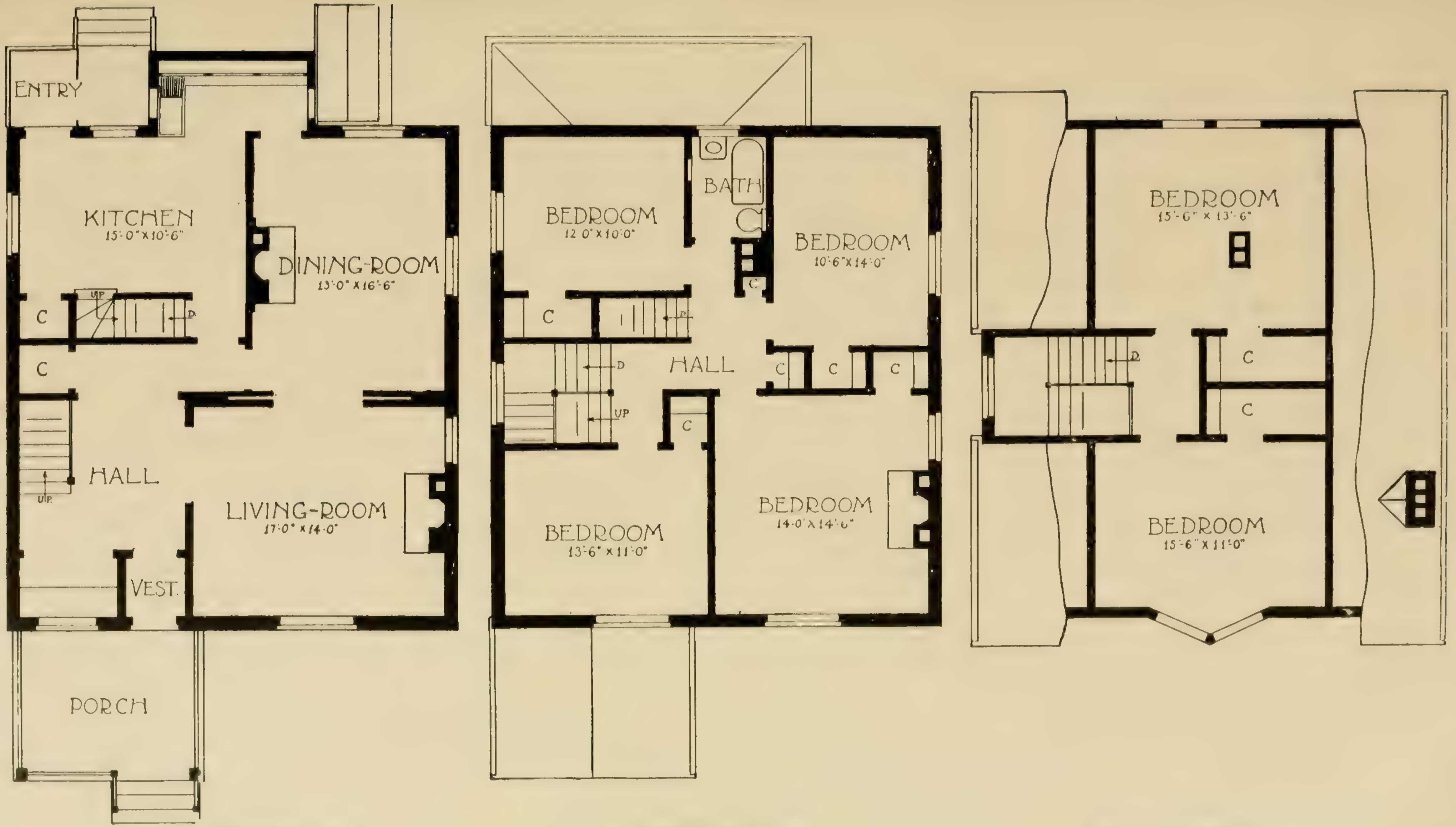


Fig. 81. Cast-Iron Heater Not Made in Sections. Water Fills Cross-Pipes and Space between Outer and Inner Shells.



THREE HOUSES FOR INDIANA STEEL COMPANY, GARY, IND.

Dean & Dean, Architects, Chicago, Ill.
Paving Brick Veneer and Plaster; Tile Roofs.



First-Story Plan. Second-Story Plan. Third-Story Plan.

THREE HOUSES FOR INDIANA STEEL COMPANY, GARY, IND.

Dean & Dean, Architects, Chicago, Ill.
Exteriors Shown on Opposite Page.

and the water above the diaphragm is forced out through the pet-cock *G*, which is kept slightly open all the time.

DIRECT HOT=WATER HEATING

A hot-water system is similar in construction and operation to one designed for steam, except that *hot water* flows through the pipes and radiators instead.

The circulation through the pipes is produced solely by the difference in weight of the water in the supply and return, due to the difference in temperature. When water is heated it expands, and thus a given volume becomes lighter and tends to rise, and the cooler water flows in to take its place; if the application of heat is kept up, the circulation thus produced is continuous. The velocity of flow depends upon the difference in temperature between the supply and return, and the height of the radiator above the boiler. The horizontal distance of the radiator from the boiler is also an important factor affecting the velocity of flow.

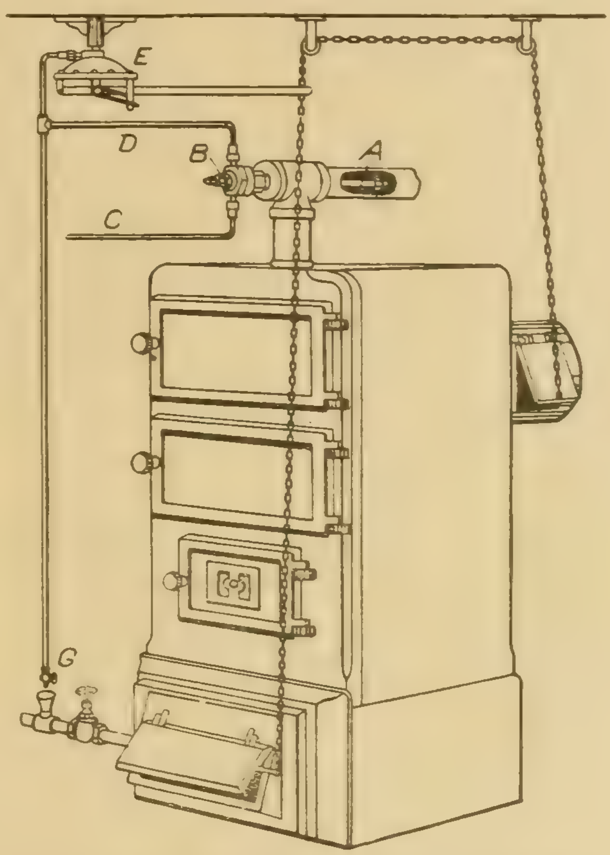


Fig. 82. Hot-Water Heater with Automatic Regulator Operated through Expansion and Contraction of Metal Rod in Flow Pipe.

This action is best shown by means of a diagram, as in Fig. 83. If a glass tube of the form shown in the figure is filled with water and held in a vertical position, no movement of the water will be noticed, because the two columns *A* and *B* are of the same weight, and therefore in equilibrium. Now, if a lamp flame be held near the tube *A*, the small bubbles of steam which are formed will show the water to be in motion, with a current flowing in the direction indicated by the arrows. The reason for this is, that, as the water in *A* is heated, it expands and becomes lighter for a given volume, and is forced upward by the heavier water in *B* falling to the bottom of the tube. The heated water flows from *A* through the connecting tube at the top, into *B*, where it takes the place of the cooler water which is settling to the bottom. If, now, the lamp be replaced by a furnace, and the columns *A* and *B* be connected at the top by inserting a radiator, the illustration will assume the practical form as utilized in hot-water heating (see Fig. 84).

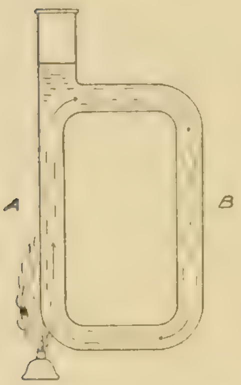


Fig. 83. Illustrating How the Heating of Water Causes Circulation.

The heat given off by the radiator always insures a difference in temperature between the columns of water in the supply and return pipes, so that as long as heat is supplied by the furnace the flow of water will continue. The greater the difference in temperature of the water in the two pipes, the greater the difference in weight, and consequently the faster the flow. The greater the height of the radiator above the heater, the more rapid will be the circulation, because the total difference in weight between the water in the supply and return risers will vary directly with their height. From the above it is evident that the rapidity of flow depends chiefly upon the *temperature* difference between the supply and return, and upon the *height of the radiator* above the heater. Another factor which must be considered in long runs of horizontal pipe is the *frictional resistance.*

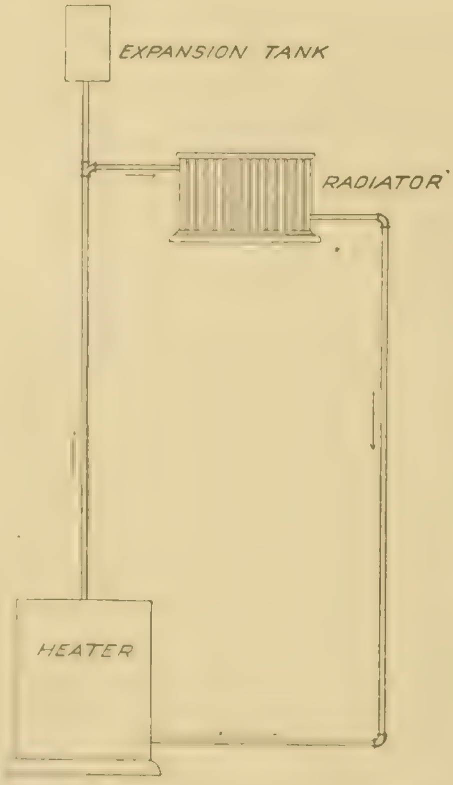


Fig. 84. Illustrating Simple Circulation in a Heating System.

Systems of Circulation. There are two distinct systems of circulation employed—one depending on the difference in temperature of the water in the supply and return pipes, called *gravity circulation*;

and another where a pump is used to force the water through the mains, called *forced circulation*. The former is used for dwellings and other buildings of ordinary size, and the latter for large buildings, and especially where there are long horizontal runs of pipe.

For gravity circulation some form of sectional cast-iron boiler is commonly used, although wrought-iron tubular boilers may be employed if desired. In the case of forced circulation, a heater designed to warm the water by means of live or exhaust steam is often used. A centrifugal or rotary pump is best adapted to this purpose, and may be driven by an electric motor or a steam engine, as most convenient.

Types of Radiating Surface. Cast-iron radiators and circulation coils are used for hot water as well as for steam. Hot-water radiators differ from steam radiators principally in having a horizontal passage at the top as well as at the bottom. This construction is necessary in order to draw off the air which gathers at the top of each loop or section. Otherwise they are the same as steam radiators, and are well adapted for the circulation of steam, and in some respects are superior to the ordinary pattern of steam radiator.

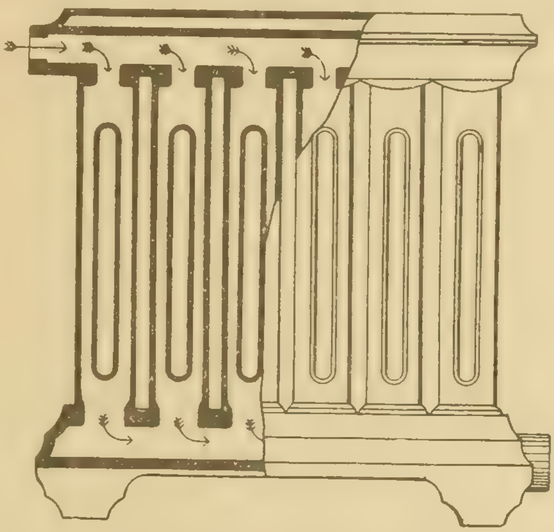


Fig. 85. Showing Construction of Radiator for Hot Water or Steam. Note Horizontal Passage along Top.

The form shown in Fig. 85 is made with an opening at the top for the entrance of water, and at the bottom for its discharge, thus insuring a supply of hot water at the top and of colder water at the bottom.

Some hot-water radiators are made with a cross-partition so arranged that all water entering passes at once to the top, from which it may take any passage toward the outlet. Fig. 86 is the more common form of radiator, and is made with continuous passages at top and bottom, the hot water being supplied at one side and drawn off at the other. The action of gravity is depended upon for making the hot and lighter water pass to the top, and the colder water sink to the bottom and flow off through the return. Hot-water radiators are usually tapped and plugged so that the pipe connections can be made either at the top or at the bottom. This is shown in Fig. 87.

Wall radiators are adapted to hot-water as well as steam heating.

Efficiency of Radiators. The efficiency of a hot-water radiator depends entirely upon the temperature at which the water is circulated. The best practical results are obtained with the water leaving the boiler at a maximum temperature of about 180 degrees in zero weather and returning at about 160 degrees; this gives an average temperature of 170 degrees in the radiators. Variations may be made, however, to suit the existing conditions of outside temperature. We have seen that an average cast-iron radiator gives off about 1.7 B.T.U. per hour per square foot of surface per degree difference in temperature between the radiator and the surrounding air, when working under ordinary conditions; and this holds true whether it is filled with steam or water.

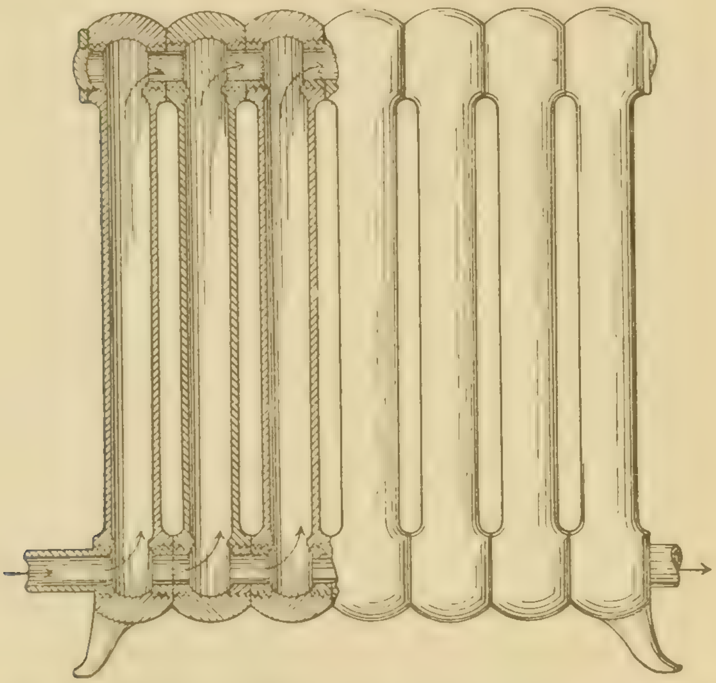


Fig. 86. Common Form of Hot-Water Radiator. Circulation Produced Wholly through Action of Gravity, Hot Water Rising to Top.

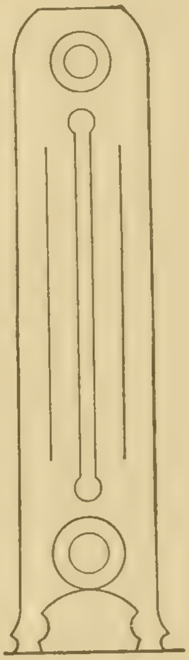


Fig. 87. End Elevation of Radiator Showing Taps at Top and Bottom for Pipe Connections.

If we assume an average temperature of 170 degrees for the water, then the difference in temperature between the radiator and the air will be 170 — 70 = 100 degrees; and this multiplied by 1.7 =

170, which may be taken as the efficiency of a hot-water radiator under the above average conditions.

This calls for a water radiator about 1.5 times as large as a steam radiator to heat a given room under the same conditions. This is common practice although some engineers multiply by the factor 1.6, which allows for a lower temperature of the water. Water leaving the boiler at 170 degrees should return at about 150; the drop in temperature should not ordinarily exceed 20 degrees.

Systems of Piping. A system of hot-water heating should produce a perfect circulation of water from the heater to the radiating surface, and thence back to the heater through the returns. The system of piping usually employed for hot-water heating is shown in Fig. 88. In this arrangement the main and branches have an inclination upward from the heater; the returns are parallel to the mains, and have an inclination downward toward the heater, connecting with it at the lowest point. The flow pipes or risers are taken from the tops of the mains, and may supply one or more radiators as required. The return risers or drops are connected with the return mains in a similar manner. In this system great care must be taken to produce a nearly equal resistance to flow in all of the branches, so that each radiator may receive its full supply of water. It will always

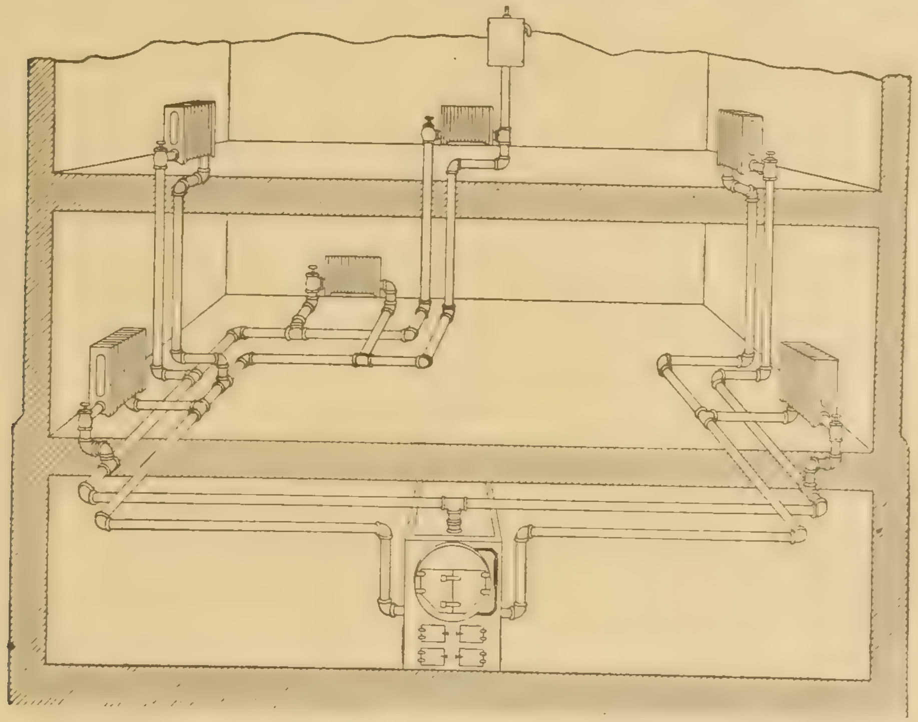


Fig. 88. System of Piping Usually Employed for Hot-Water Heating.

be found that the principal current of heated water will take the path of least resistance, and that a small obstruction or irregularity in the piping is sufficient to interfere greatly with the amount of heat received in the different parts of the same system.

Some engineers prefer to carry a single supply main around the building, of sufficient size to supply all the radiators, bringing back a single return of the same size. Practice has shown that in general it is not well to use pipes over 8 or 10 inches in diameter; if larger pipes are required, it is better to run two or more branches.

The boiler, if possible, should be centrally located, and branches carried to different parts of the building. This insures a more even circulation than if all the radiators are supplied from a single long main, in which case the circulation is liable to be sluggish at the farther end.

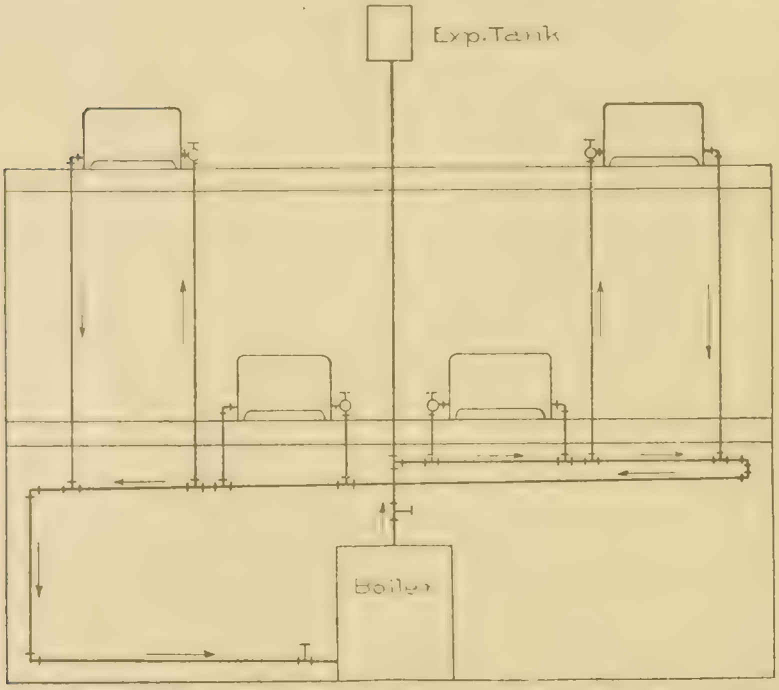


Fig. 89. System of Hot-Water Piping Especially Adapted to Apartment Buildings where Each Flat Has a Separate Heater

The arrangement shown in Fig. 89 is similar to the circuit system for steam, except that the radiators have two connections instead of one. This method is especially adapted to apartment houses, where each flat has its separate heater, as it eliminates a separate return main, and thus reduces, by practically one-half, the amount of piping in the basement. The supply risers are taken from the top of the main; while the returns should connect into the side a short distance beyond, and in a direction *away* from the boiler. When this system is used, it is necessary to enlarge the radiators slightly as the distance from the boiler increases.

In flats of eight or ten rooms, the size of the last radiator may be increased from 10 to 15 per cent, and the intermediate ones proportionally, at the same time keeping the main of a large and uniform size for the entire circuit.

Overhead Distribution. This system of piping is shown in Fig. 90. A single riser is carried directly to the expansion tank, from which branches are taken to supply the various drops to which the radiators are connected. An important advantage in connection with this system is that the air rises at once to the expansion tank, and escapes through the vent, so that air-valves are not required on the radiators.

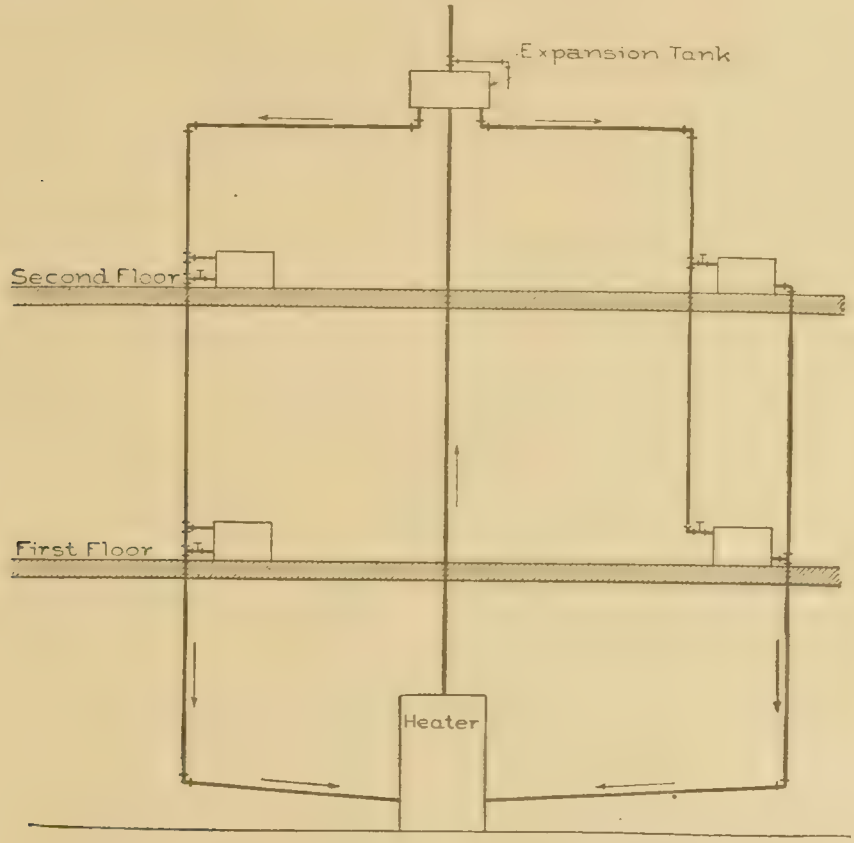


Fig. 90. "Overhead" Distribution System of Hot-Water Piping.

At the same time, it has the disadvantage that the water in the tank is under less pressure than in the heater; hence it will boil at a lower temperature. No trouble will be experienced from this, however, unless the temperature of the water is raised above 212 degrees.

Expansion Tank. Every system for hot-water heating should be connected with an expansion tank placed at a point somewhat above the highest radiator. The tank must in every case be connected to a line of piping which cannot by any possible means be shut off from the boiler. When water is heated, it expands a certain amount, depending upon the temperature to which it is raised; and a tank or reservoir should always be provided to care for this increase in volume.

Expansion tanks are usually made of heavy galvanized iron of one of the forms shown in Figs. 91 and 92, the latter form being used where the headroom is limited. The connection from the heating system enters the bottom of the tank, and an open vent pipe is taken from the top. An overflow connected with a sink or drain-pipe should be provided. Connections should be made with the water supply both at the boiler and at the expansion tank, the former to be used when first filling the system, as by this means all air is driven from the bottom upward and is discharged through the vent at the expansion tank. Water that is added afterward may be supplied directly to the expansion tank, where the water-line can be noted in the gauge-glass. A ball-cock is sometimes arranged to keep the water-line in the tank at a constant level.

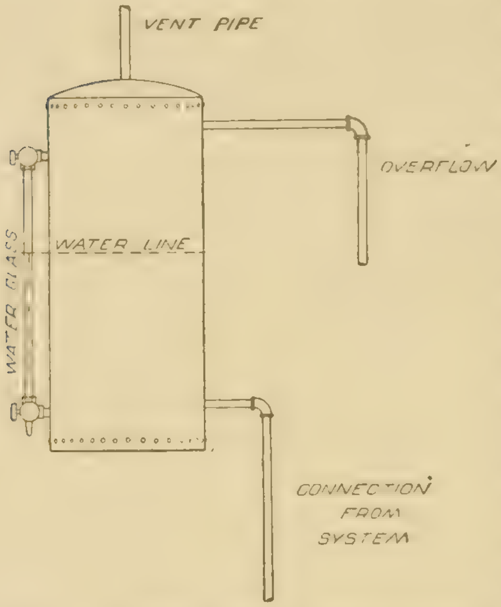


Fig. 91. A Common Form of Galvanized-Iron Expansion Tank.

An *altitude gauge* is often placed in the basement with the colored hand or pointer set to indicate the normal water-line in the expansion tank. When the movable hand falls below the fixed one, more water may be added, as required, through the supply pipe at the boiler. When the tank is placed in an attic or roof space where there is danger of freezing, the expansion pipe may be connected into the side of the

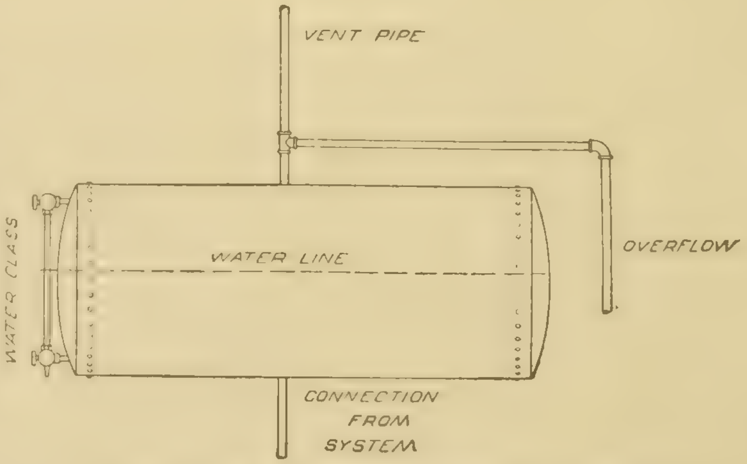


Fig. 92. Form of Expansion Tank Used where Headroom is Limited.

tank, 6 or 8 inches from the bottom, and a circulation pipe taken from the lower part and connected with the return from an upper-floor radiator. This produces a slow circulation through the tank, and keeps the water warm.

The size of the expansion tank depends upon the volume of water contained in the system, and on the temperature to which it is heated. The following rule for computing the capacity of the tank may be used with satisfactory results:

Square feet of radiation, *divided by* 40, equals required capacity of tank in gallons.

Air=Venting. One very important point to be kept in mind in the design of a hot-water system, is the removal of air from the pipes and radiators. When the water in the boiler is heated, the air it contains forms into small bubbles which rise to the highest points of the system.

In the arrangement shown in Fig. 88, the main and branches grade upward from the boiler, so that the air finds its way into the radiators, from which it may be drawn off by means of the air-valves.

A better plan is that shown in Fig. 89. In this case the expansion pipe is taken directly off the top of the main over the boiler, so that the larger part of the air rises directly to the expansion tank and escapes through the vent pipe. The same action takes place in the overhead system shown in Fig. 90, where the top of the main riser is connected with the tank. Every high point in the system and every radiator, except in the downward system with top supply connection, should be provided with an air-valve.

Pipe Connections. There are various methods of connecting the radiators with the mains and risers. Fig. 93 shows a radiator connected with the horizontal flow and return mains, which are located below the floor. The manner of connecting with a vertical riser and return drop is shown in Fig. 94. As the water tends to flow to the highest point, the radiators on the lower floors should be favored by making the connection at the top of the riser and taking the pipe for the upper floors from the side as shown. Fig. 95 illustrates the manner of connecting with a radiator on an upper floor where the supply is connected at the top of the radiator.

The connections shown in Figs. 96 and 97 are used with the overhead system shown in Fig. 90.

Where the connection is of the form shown at the left in Fig. 90, the cooler water from the radiators is discharged into the supply pipe again, so that the water furnished to the radiators on the lower floors is at a lower temperature, and the amount of heating surface must be correspondingly increased to make up for this loss, as already described for the circuit system.

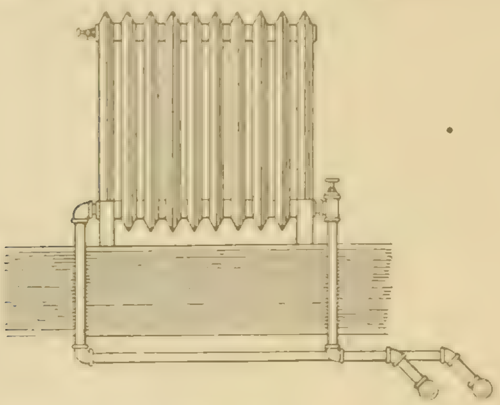


Fig. 93. Radiator Connected with Horizontal Flow and Return Mains Located below Floor.

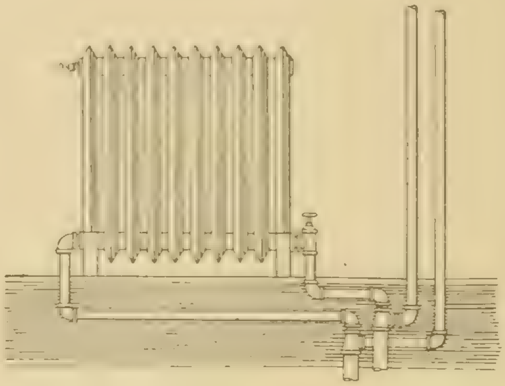


Fig. 94. Radiator Connected to Vertical Riser and Return Drop.

For example, if in the case of Fig. 90 we assume the water to leave at 180 degrees and return at 160, we shall have a drop in temperature of 10 degrees on each floor; that is, the water will enter the radiator on the second floor at 180 degrees and leave it at 170, and will enter the radiator on the first floor at 170 and leave it at 160.

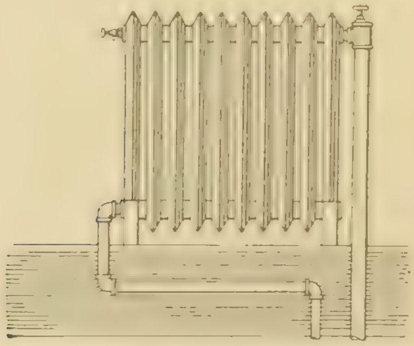


Fig. 95. Upper-Floor Radiator with Supply Connected at Top.

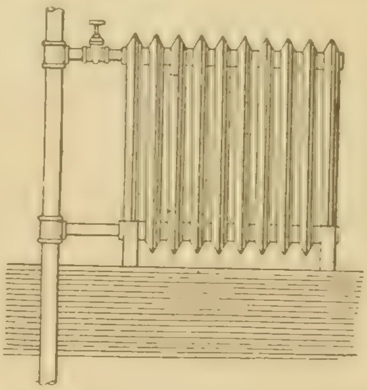


Fig. 96. Radiator Connections, Overhead Distribution System.

The average temperatures will be 175 and 165, respectively. The efficiency in the first case will be 175 — 70 = 105; and 105 × 1.5 = 157. In the second case, 165 — 70 = 95; and 95 × 1.5 = 142; so that the radiator on the first floor will have to be larger than that on the second floor in the ratio of 157 to 142, in order to do the same work.

This is approximately an increase of 10 per cent for each story downward to offset the cooling effect; but in practice the supply drops are made of such size that only a part of the water is by-passed through the radiators. For this reason an increase of 5 per cent for each story downward is probably sufficient in ordinary cases.

Where the radiators discharge into a separate return as in the case of Fig. 88, or those at the right in Fig. 90, we may assume the temperature of the water to be the same on all floors, and give the radiators an equal efficiency.

In a dwelling-house of two stories, no difference would be made in the sizes of radiators on the two floors; but in the case of a tall office building, corrections would necessarily be made as above described.

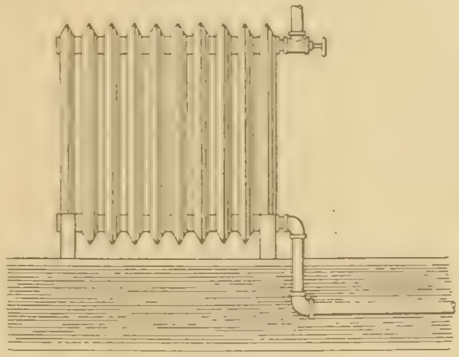


Fig. 97. Another Form of Radiator Connection, Overhead Distribution System.

Where circulation coils are used, they should be of a form which will tend to produce a flow of water through them. Figs. 98, 99, and 100 show different ways of making up and connecting these coils. In Figs. 98 and 100, supply pipes may be either drops or risers; and in the former case the return in Fig. 100 may be carried back, if desired, into the supply drop, as shown by the dotted lines.

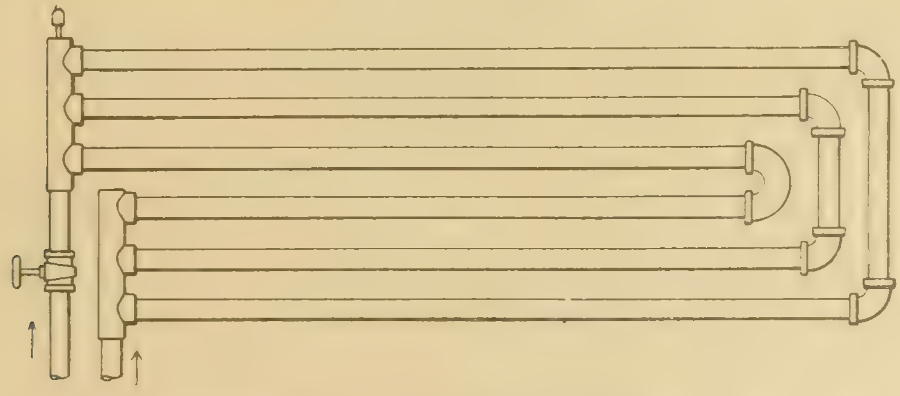


Fig. 98. Circulation Coil, One Method of Construction. Supply Pipes may be Either Drops or Risers.

Combination Systems. Sometimes the boiler and piping are arranged for either steam or hot water, since the demand for a higher or lower temperature of the radiators might change.

The object of this arrangement is to secure the advantages of a hot-water system for moderate temperatures, and of steam heating for extremely cold weather.

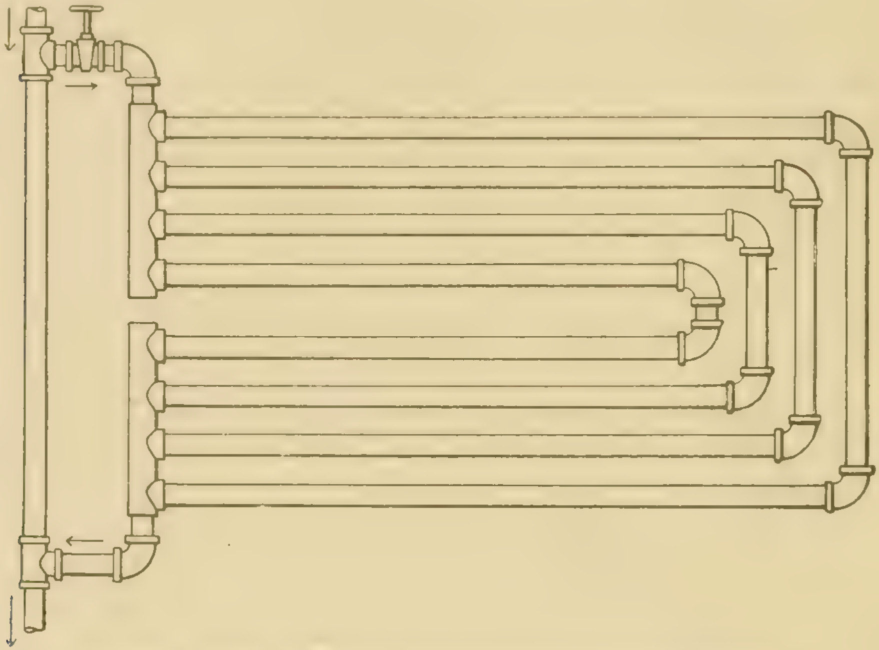


Fig. 99. Another Method of Building Up a Circulation Coil.

As less radiating surface is required for steam heating, there is an advantage due to the reduction in first cost. This is of considerable importance, as a heating system must be designed of such dimensions as to be capable of warming a building in the coldest weather; and this involves the expenditure of a considerable amount for radiating surfaces, which are needed only at rare intervals. A combination system of hot-water and steam heating requires, *first*, a heater or boiler

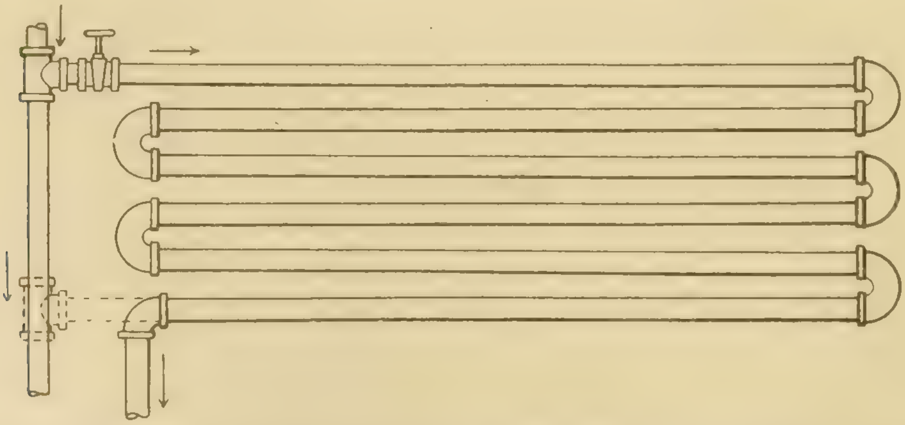


Fig. 100. Circulation Coil with Either Drop or Riser Supply. In former case, return may be carried into Supply Drop as shown by Dotted Lines.

which will answer for either purpose; *second*, a system of piping which will permit the circulation of either steam or hot water; and *third*, the use of radiators which are adapted to both kinds of heating. These requirements will be met by using a steam boiler provided with all the fittings required for steam heating, but so arranged that the damper regulator may be closed by means of valves when the system is to be used for hot-water heating. The addition of an expansion tank is required, which must be so arranged that it can be shut off when the system is used for steam heating. The system of piping shown in Fig. 88 is best adapted for a combination system, although an overhead distribution as shown in Fig. 90 may be used by shutting off the vent and overflow pipes, and placing air-valves on the radiators.

While this system has many advantages in the way of cost over the complete hot-water system, the labor of changing from steam to hot water will in some cases be troublesome; and should the connections to the expansion tank not be opened, serious results would follow.

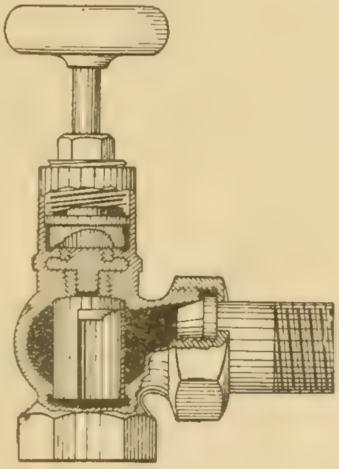


Fig. 101. Radiator Valve for Hot-Water Work.

Valves and Fittings. Gate-valves should always be used in connection with hot-water piping, although angle-valves may be used at the radiators. There are several patterns of radiator valves made especially for hot-water work; their chief advantage lies in a device for quick closing, usually a quarter-turn or half-turn being sufficient to open or close the valve. Two different designs are shown in Figs. 101 and 102.

It is customary to place a valve in only one connection, as that is sufficient to stop the flow of water through the radiator; a fitting known as a *union elbow* is often employed in place of the second valve. (See Fig. 103.)

Air-Valves. The ordinary pet-cock air-valve is the most reliable for hot-water radiators, although there are several forms of automatic valves which are claimed to give satisfaction. One of these is shown in Fig. 104. This is similar in construction to a steam trap. As air collects in the chamber, and the water-line is lowered, the float drops, and in so doing opens a small valve at the top of the chamber, which allows the air to escape. As the water flows in to take its place, the float is forced upward and the valve is closed.

All radiators which are supplied by risers from below, should be provided with air-valves placed in the top of the last section at the return end. If they are supplied by drops from an overhead system, the air will be discharged at the expansion tank, and air-valves will not be necessary at the radiators.

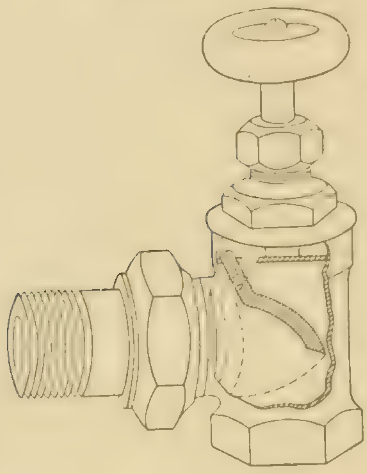


Fig. 102. Another Type of Hot-Water Radiator Valve

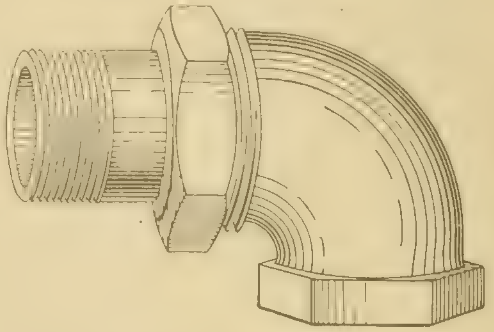


Fig. 103. Union Elbow.

Fittings. All fittings, such as elbows, tees, etc., should be of the *long-turn* pattern. If the common form is used, they should be a size larger than the pipe, bushed down to the proper size. The long-turn fittings, however, are preferable, and give a much better appearance. Connections between the radiators and risers may be made with the ordinary short-pattern fittings, as those of the other form are not well adapted to the close connections necessary for this work.

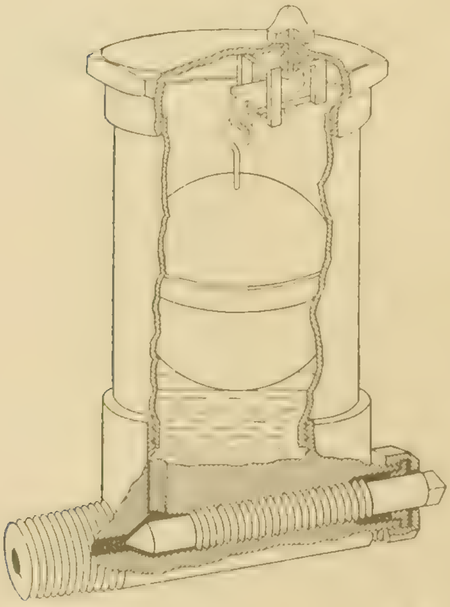


Fig. 104. Automatic Air-Valve for Hot Water Radiator. Operated by a Float.

Pipe Sizes. The size of pipe required to supply any given radiator depends upon four conditions; *first,* the size of the radiator; *second,* its elevation above the boiler; *third,* the length of pipe required to connect it with the boiler; and *fourth,* the difference in temperature between the supply and the return.

As it would be a long and rather complicated process to work out the required size of each pipe for a heating system, Tables XXVI and XXVII have been prepared, covering the usual conditions to be met with in practice.

TABLE XXVI

Direct Radiating Surface Supplied by Mains of Different Sizes and Lengths of Run

Size of Pipe	Square Feet of Radiating Surface								
	100 ft. Run	200 ft. Run	300 ft. Run	400 ft. Run	500 ft. Run	600 ft Run	700 ft. Run	800 ft. Run	1,000 ft Run
1 in.	30								
1¼ "	60	50							
1½ "	100	75	50						
2 "	200	150	125	100	75				
2½ "	350	250	200	175	150	125			
3 "	550	400	300	275	250	225	200	175	150
3½ "	850	600	450	400	350	325	300	250	225
4 "	1,200	850	700	600	525	475	450	400	350
5 "		1,400	1,150	1,000	700	850	775	725	650
6 "				1,600	1,400	1,300	1,200	1.150	1,000
7 "							1,706	1.600	1,500

These quantities have been calculated on a basis of 10 feet difference in elevation between the center of the heater and the radiators, and a difference in temperature of 17 degrees between the supply and the return.

TABLE XXVII

Radiating Surface on Different Floors Supplied by Pipes of Different Sizes

Size of Riser	Square Feet of Radiating Surface					
	1st Story	2d Story	3d Story	4th Story	5th Story	6th Story
1 in.	30	55	65	75	85	95
1¼ "	60	90	110	125	140	160
1½ "	100	140	165	185	210	240
2 "	200	275	375	425	500	
2½ "	350	475				
3 "	550					
3½ "	850					

Table XXVI gives the number of square feet of direct radiation which different sizes of mains and branches will supply for varying lengths of run.

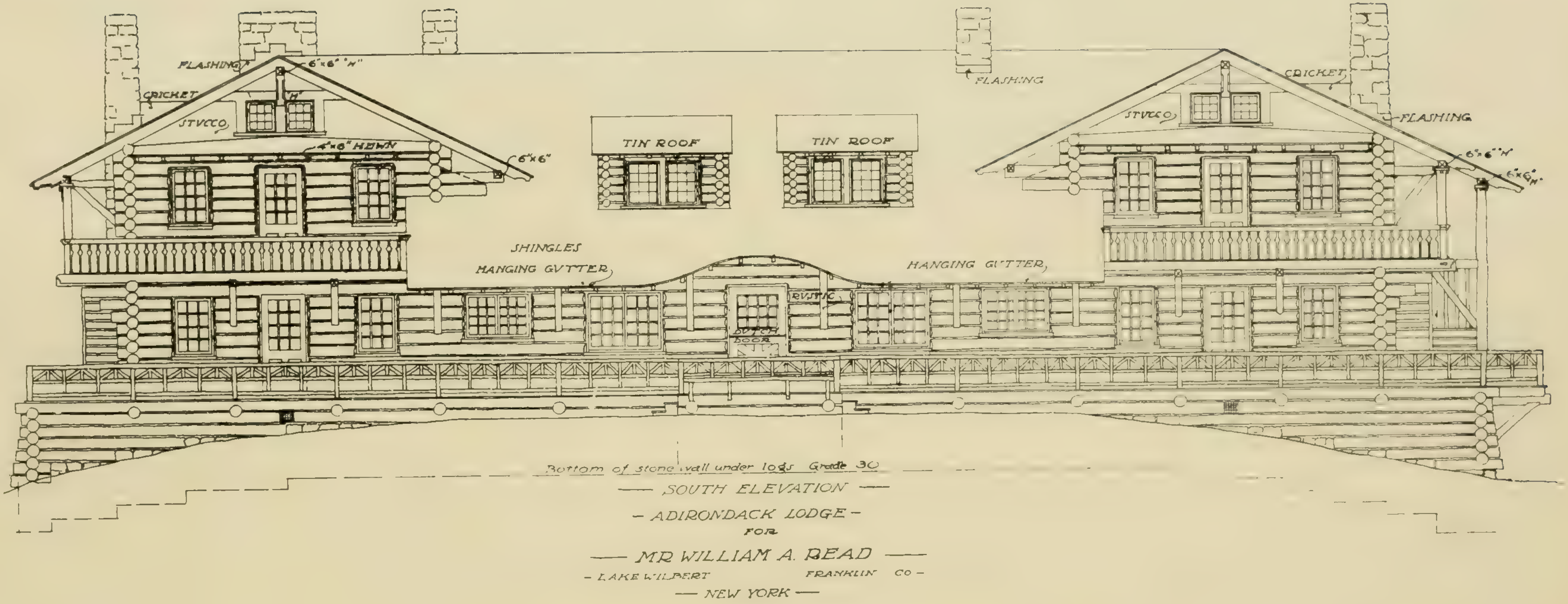
Table XXVI may be used for all horizontal mains. For vertical risers or drops, Table XXVII may be used. This has been computed for the same difference in temperature as in the case of Table XXVI (17 degrees), and gives the square feet of surface which different sizes of pipe will supply on the different floors of a building, assuming the height of the stories to be 10 feet. Where a single riser is carried to the top of a building to supply the radiators on the floors below, by drop pipes, we must first get what is called the *average elevation of the system* before taking its size from the table. This may be illustrated by means of a diagram (see Fig. 105).

In *A* we have a riser carried to the third story, and from there a drop brought down to supply a radiator on the first floor. The elevation available for producing a flow in the riser is only 10 feet, the same as though it extended only to the radiator. The water in the two pipes above the radiator is practically at the same temperature, and therefore in equilibrium, and has no effect on the flow of the water in the riser. (Actually there would be some radiation from the pipes, and the return, above the radiator, would be slightly cooler, but for purposes of illustration this may be neglected). If the radiator was on the second floor the elevation of the system would be 20 feet (see *B*); and on the third floor, 30 feet; and so on. The distance which the pipe is carried above the first radiator which it supplies has but little effect in producing a flow, especially if covered, as it should be in practice. Having seen that the flow in the main riser depends upon the elevation of the radiators, it is easy to see that the way in which it is distributed on the different floors must be considered. For example, in *B*, Fig. 105, there will be a more rapid flow through the riser with the radiators as shown, than there would be if they were reversed and the largest one were placed upon the first floor.

We get the average elevation of the system by multiplying the square feet of radiation on each floor by the elevation above the heater, then adding these products together and dividing the same by the total radiation in the whole system. In the case shown in *B*, the average elevation of the system would be

$$\frac{(100 \times 30) + (50 \times 20) + (25 \times 10)}{100 + 50 + 25} = 24 \text{ feet};$$

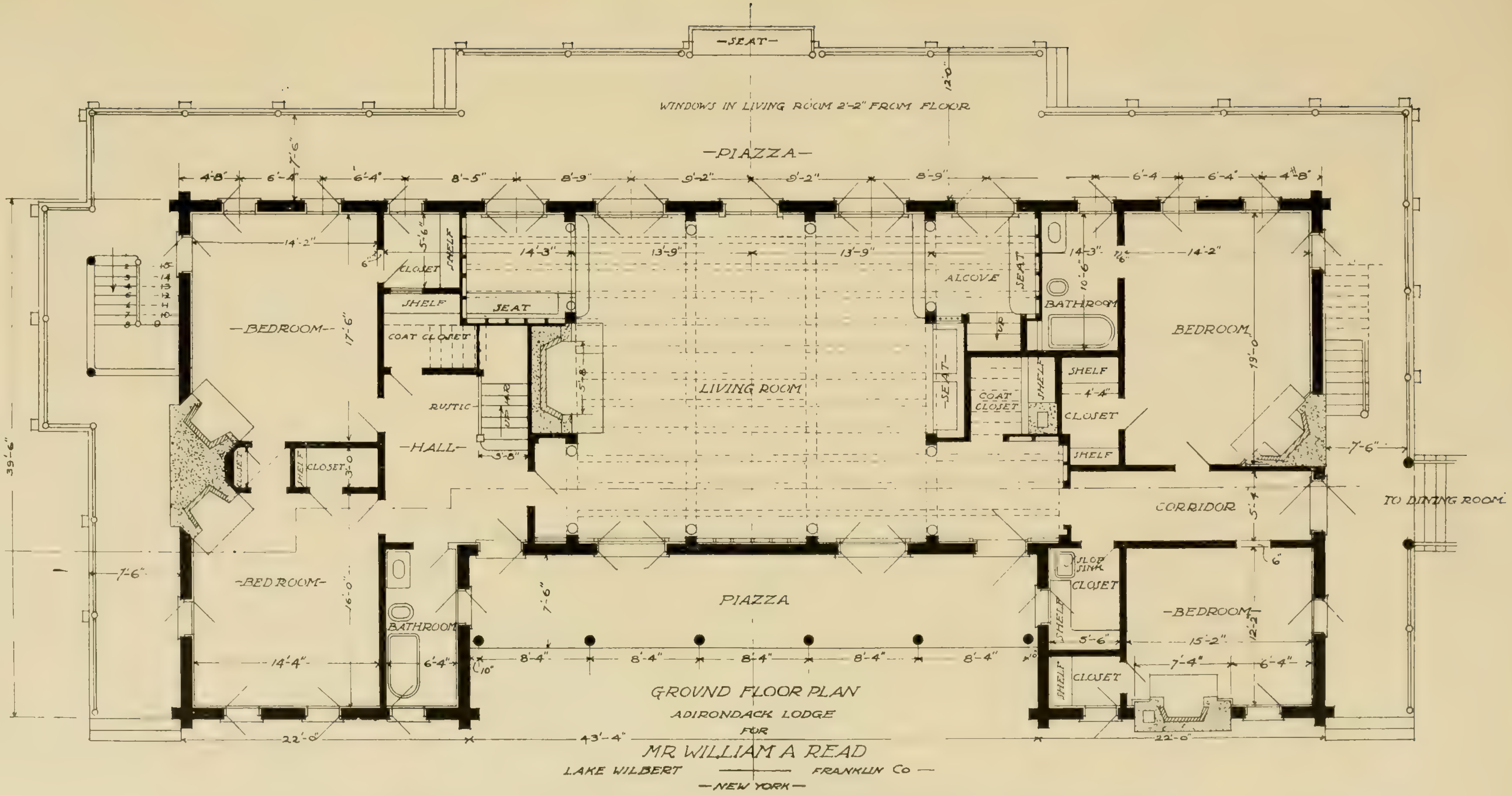
and we must proportion the main riser the same as though the whole radiation were on the second floor. Looking in Table XXVII, we find, for the second story, that a $1\frac{1}{2}$-inch pipe will supply 140 square



FRONT ELEVATION OF ADIRONDACK LODGE FOR WILLIAM A. READ, ESQ.

Davis, McGrath & Shepard, Architects, New York.

Plan Shown on Opposite Page.



GROUND-FLOOR PLAN OF ADIRONDACK LODGE FOR WILLIAM A. READ, ESQ.

Davis, McGrath & Shepard, Architects, New York.

Front Elevation Shown on Opposite Page.

feet; and a 2-inch pipe, 275 feet. Probably a 1½-inch pipe would be sufficient.

Although the height of stories varies in different buildings, 10 feet will be found sufficiently accurate for ordinary practice.

INDIRECT HOT-WATER HEATING

This is used under the same conditions as indirect steam, and the heaters used are similar to those already described. Special attention is given to the form of the sections, in order that there may be an even distribution of water through all parts of them. As the stacks are placed in the basement of a building, and only a short distance above the boiler, extra large pipes must be used to secure a proper circulation, for the *head* producing flow is small. The stack

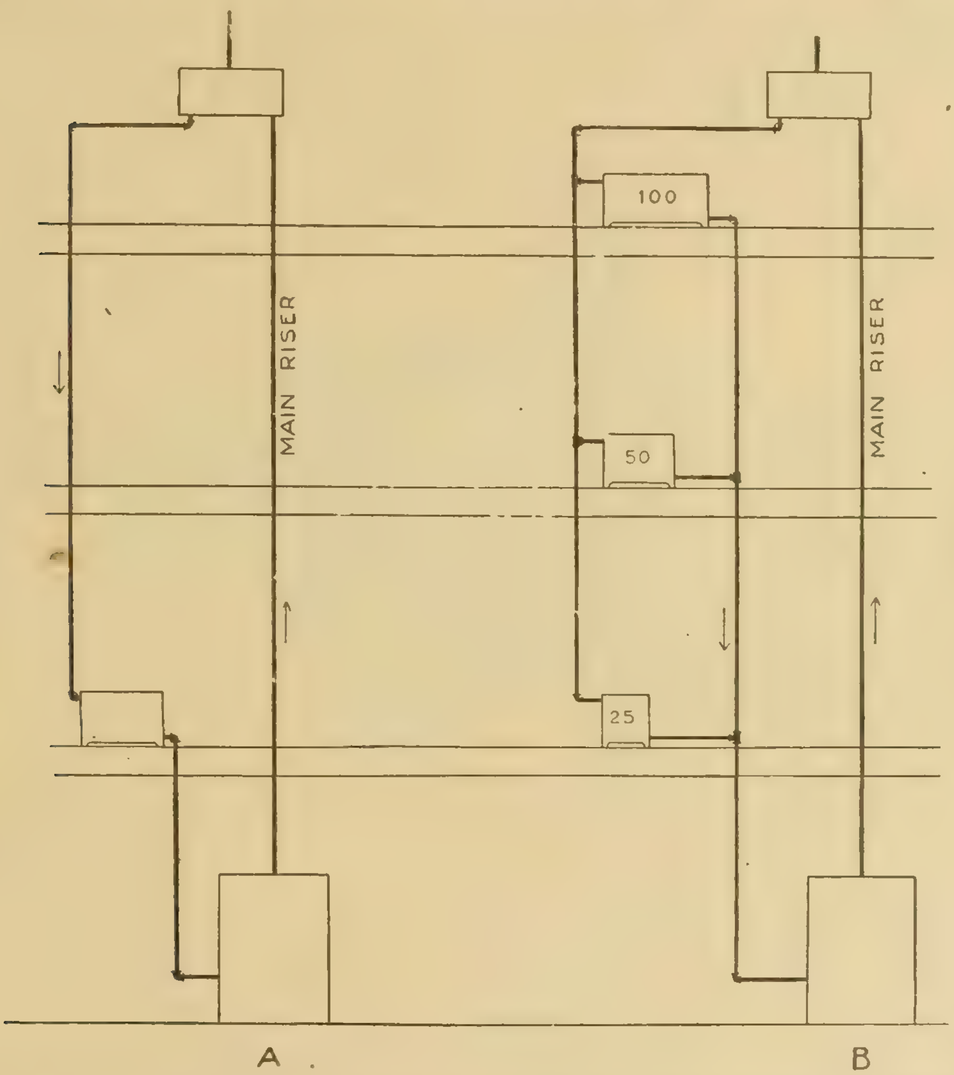


Fig. 105. Diagram to Illustrate Finding of Average Elevation of Heating System.

casings, cold-air and warm-air pipes, and registers are the same as in steam heating.

Types of Radiators. The radiators for indirect hot-water heating are of the same general form as those used for steam. Those shown in Figs. 52, 53, 56, 106, and 107 are common patterns. The *drum pin,* Fig. 106, is an excellent form, as the method of making the connections insures a uniform distribution of water through the stack.

Fig. 107 shows a radiator of good form for water circulation, and also of good depth, which is a necessary point in the design of hot-water radiators. They should be not less than 12 or 15 inches deep for good results. Box coils of the form given for steam may also be used, provided the connections for supply and return are made of good size.

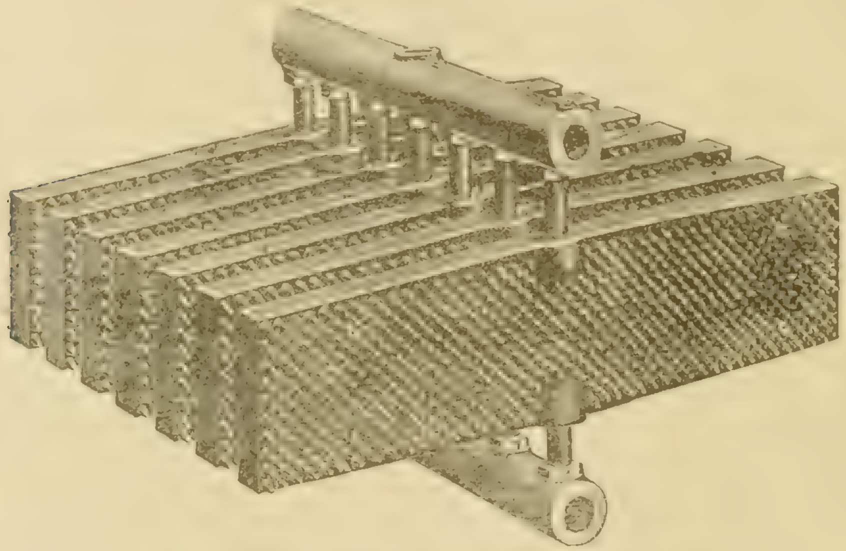


Fig. 106. "Drum Pin" Indirect Hot-Water Radiator.

Size of Stacks. As indirect hot-water heaters are used principally in the warming of dwelling-houses, and in combination with direct radiation, the easiest method is to compute the surfaces required for direct radiation, and multiply these results by 1.5 for pin radiators of good depth. For other forms the factor should vary from 1.5 to 2, depending upon the depth and proportion of free area for air-flow between the sections.

If it is desired to calculate the required surface directly by the thermal unit method, we may allow an efficiency of from 360 to 400 for good types in zero weather.

In schoolhouse and hospital work, where larger volumes of air are warmed to lower temperatures, an efficiency as high as 500 B. T. U. may be allowed for radiators of good form.

Flues and Casings. For cleanliness, as well as for obtaining the best results, indirect stacks should be hung at one side of the register or flue receiving the warm air, and the cold-air duct should enter beneath the heater at the other side. A space of at least 10 inches, and preferably 12, should be allowed for the warm air above the stack. The top of the casing should pitch upward toward the warm-air outlet at least an inch in its length. A space of from 8 to 10 inches should be allowed for cold air below the stack.

As the amount of air warmed per square foot of heating surface is less than in the case of steam, we may make the flues somewhat smaller as compared with the size of heater. The following proportions may be used under usual conditions for dwelling-houses: $1\frac{1}{2}$ square inches per square foot of radiation for the first floor, $1\frac{1}{4}$ square inches for the second floor, and $1\frac{1}{4}$ square inches for the cold-air duct.

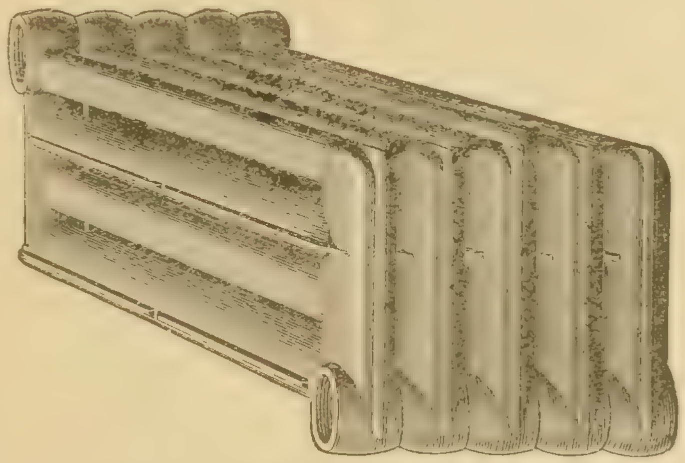


Fig. 16. Indirect Hot-Water Radiator.

Pipe Connections. In indirect hot-water work, it is not desirable to supply more than 80 to 100 square feet of radiation from a single connection. When the requirements call for larger stacks, they should be divided into two or more groups according to size.

It is customary to carry up the main from the boiler to a point near the basement ceiling, where it is air-vented through a small pipe leading to the expansion tank. The various branches should grade downward and connect with the tops of the stacks. In this way, all air, both from the boiler and from the stacks, will find its way to the highest point in the main, and be carried off automatically.

As an additional precaution, a pet-cock air-valve should be placed in the last section of each stack, and brought out through the casing by means of a short pipe.

TABLE XXVIII

Radiating Surface Supplied by Pipes of Various Sizes—Indirect Hot-Water System

Diameter of Pipe	Square Feet of Radiating Surface			
	100 Ft. Run	200 Ft. Run	300 Ft. Run	400 Ft. Run
1 in.	15			
1¼ "	30	25		
1½ "	50	40	25	
2 "	100	75	60	50
2½ "	175	125	100	90
3 "	275	200	150	140
3½ "	425	300	225	200
4 "	600	425	350	300
5 "		700	575	500
6 "				800
7 "				1,200

Some engineers make a practice of carrying the main to the ceiling of the first story, and then dropping to the basement before branching to the stacks, the idea being to accelerate the flow of water through the main, which is liable to be sluggish on account of the small difference in elevation between the boiler and stacks. If the return leg of the loop is left uncovered, there will be a slight drop in temperature, tending to produce this result; but in any case it will be exceedingly small. With supply and return mains of suitable size and properly graded, there should be no difficulty in securing a good circulation in basements of average height.

Pipe Sizes. As the difference in elevation between the stacks and the heater is necessarily small, the pipes should be of ample size to offset the slow velocity of flow through them. The sizes mentioned in Table XXVIII, for runs up to 400 feet, will be found to supply ample radiating surface for ordinary conditions. Some engineers make a practice of using somewhat smaller pipes, but the larger sizes will in general be found more satisfactory.

CARE AND MANAGEMENT OF HOT-WATER HEATERS

The directions given for the care of steam-heating boilers apply in a general way to hot-water heaters, as to the methods of caring for the fires and for cleaning and filling the heater. Only the special points of difference need be considered. Before building the fire, all the pipes and radiators must be full of water, and the expansion tank should be partially filled as indicated by the gauge-glass. Should the water in any of the radiators fail to circulate, see that the valves are wide open and that the radiator is free from air. Water must always be added at the expansion tank when for any reason it is drawn from the system.

The required temperature of the water will depend upon the outside conditions, and only enough fire should be carried to keep the rooms comfortably warm. Thermometers should be placed in the flow and return pipes near the heater, as a guide. Special forms are made for this purpose, in which the bulb is immersed in a bath of oil or mercury (see Fig. 108).

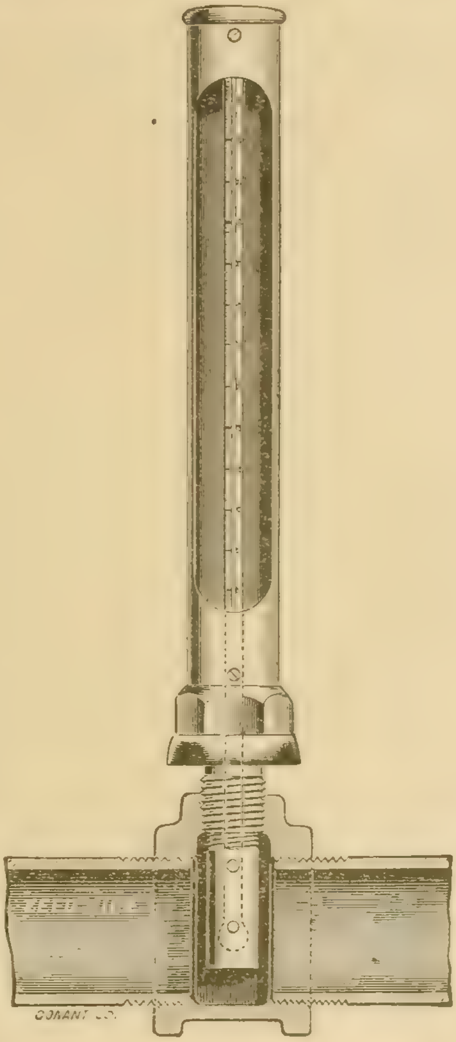


Fig. 108. Thermometer Attached to Feed-Pipe near Heater, to Determine Temperature of Water.

FORCED HOT-WATER CIRCULATION

While the gravity system of hot-water heating is well adapted to buildings of small and medium size, there is a limit to which it can be carried economically. This is due to the slow movement of the water, which calls for pipes of excessive size. To overcome this difficulty, pumps are used to force the water through the mains at a comparatively high velocity.

The water may be heated in a boiler in the same manner as for gravity circulation, or exhaust steam may be utilized in a feed-water heater of large size. Sometimes part of the heat is derived from an economizer placed in the smoke passage from the boilers.

Systems of Piping. The mains for forced circulation are usually run in one of two ways. In the *two-pipe system*, shown in Fig. 109, the supply and return are carried side by side, the former reducing in size, and the latter increasing as the branches are taken off.

The flow through the risers is produced by the difference in pressure in the supply and return mains; and as this is greatest nearest the pump, it is necessary to place throttle-valves in the risers to prevent short-circuiting and to secure an even distribution through all parts of the system.

Fig. 110 shows the *single-pipe* or *circuit system.* This is similar to the one already described for gravity circulation, except that it can be used on a much larger scale.

A single main is carried entirely around the building in this case, the ends being connected with the suction and discharge of the pump as shown.

As the pressure or head in the main drops constantly throughout the circuit, from the discharge of the pump back to the suction, it is evident that if a supply riser be taken off at any point, and the return be connected into the main a short distance along the line, there will be a sufficient difference in pressure between the two points to produce a circulation through the two risers and the connecting radiators. A distance of 8 or 10 feet between the connections is usually ample to produce the necessary circulation, and even less if the supply is taken from the top of the main and the return connected into the side.

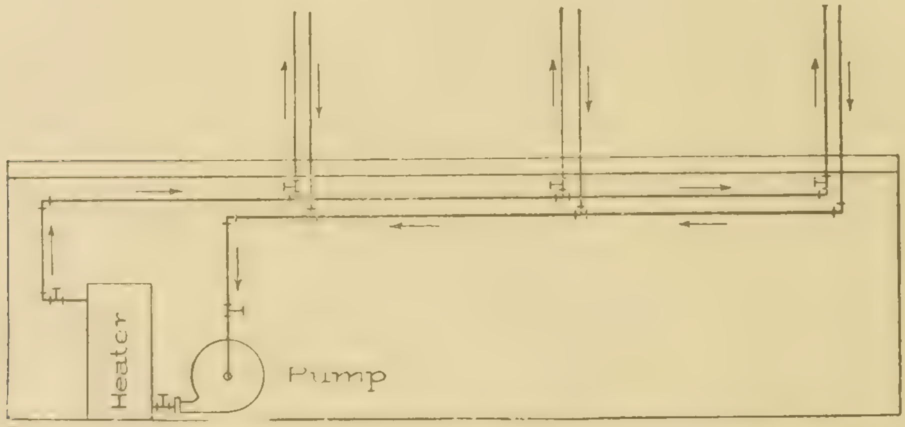


Fig. 109. "Two Pipe" System for Forced Hot-Water Circulation.

Sizes of Mains and Branches. As the velocity of flow is independent of the temperature and elevation when a pump is used, it is necessary to consider only the volume of water to be moved and the length of run.

The volume is found by the equation

$$Q = \frac{R\ E}{500\ T}$$

in which

Q = Gallons of water required per minute;
R = Square feet of radiating surface to be supplied;
E = Efficiency of radiating surface in B. T. U. per sq. foot per hour;
T = Drop in temperature of the water in passing through the heating system.

In systems of this kind, where the circulation is comparatively rapid, it is customary to assume a drop in temperature of 30° to 40°, between the supply and return.

Having determined the gallons of water to be moved, the required size of main can be found by assuming the velocity of flow, which for pipes from 5 to 8 inches in diameter may be taken at 400 to 500 feet per minute. A velocity as high as 600 feet is sometimes allowed for pipes of large size, while the velocity in those of smaller diameter should be proportionally reduced to 250 or 300 feet for a 3-inch pipe. The next step is to find the pressure or head necessary to force the water through the main at the given velocity. This in general should not exceed 50 or 60 feet, and much better pump efficiencies will be obtained with heads not exceeding 35 or 40 feet.

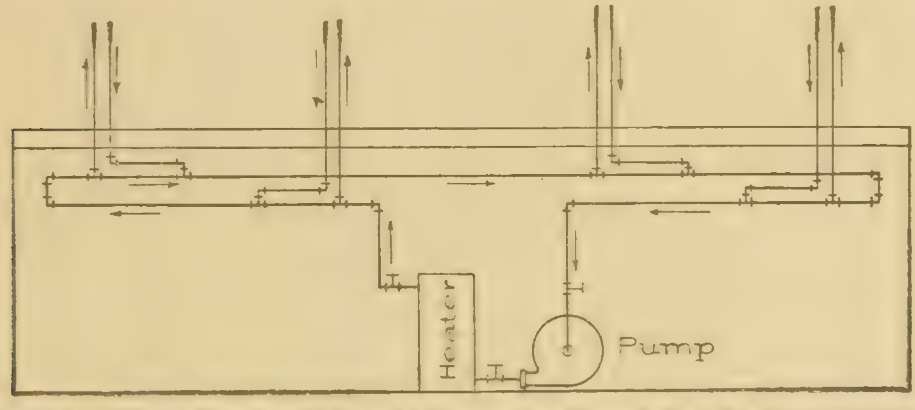


Fig. [illegible]. "Single-Pipe" or "Circuit" System for Forced Hot-Water Circulation.

As the water in a heating system is in a state of equilibrium, the only power necessary to produce a circulation is that required to overcome the friction in the pipes and radiators; and, as the area of the passageways through the latter is usually large in comparison with the former, it is customary to consider only the head necessary to force the water through the mains, taking into consideration the additional friction produced by valves and fittings.

Each long-turn elbow may be taken as adding about 4 feet to the length of pipe; a short-turn fitting, about 9 feet; 6-inch and 4-inch swing check-valves, 50 feet and 25 feet, respectively; and 6-inch and 4-inch globe check-valves, 200 feet and 130 feet, respectively.

Table XXIX is prepared especially for determining the size of mains for different conditions, and is used as follows:

Example. Suppose that a heating system requires the circulation of 480 gallons of water per minute through a circuit main 600 feet in length. The pipe contains 12 long-turn elbows and 1 swing check-valve. What diameter of main should be used?

Assuming a velocity of 480 feet per minute as a trial velocity, we follow along the line corresponding to that velocity, and find that a 5-inch pipe will deliver the required volume of water under a head of 4.9 feet for each 100 feet length of run.

The actual length of the main, including the equivalent of the fittings as additional length, is

$$600 + (12 \times 9) + 50 = 758 \text{ feet};$$

hence the total head required is $4.9 \times 7.58 = 37$ feet. As both the assumed velocity and the necessary head come within practicable limits, this is the size of pipe which would probably be used. If it were desired to reduce the power for running the pump, the size of main could be increased. That is, Table XXIX shows that a 6-inch pipe would deliver the same volume of water with a friction head of only about 2 feet per 100 feet in length, or a total head of $2 \times 7.58 = 15$ feet.

The risers in the circuit system are usually made the same size as for gravity work. With double mains, as shown in Fig. 109, they may be somewhat smaller, a reduction of one size for diameters over $1\frac{1}{4}$ inches being common

The branches connecting the risers with the mains may be proportioned from the combined areas of the risers. When the branches are of considerable size, the diameter may be computed from the available head and volume of water to be moved.

Pumps. Centrifugal pumps are usually employed in connection with forced hot-water circulation, in preference to pumps of the piston or plunger type. They are simple in construction, having no valves, produce a continuous flow of water, and, for the low heads

TABLE XXIX

Capacity in Gallons per Minute Discharged at Velocities of 300 to 540 Feet per Minute—Also Friction Head in Feet, per 100 Feet Length of Pipe

	DIAMETER OF PIPE											
	3-Inch		4-Inch		5-Inch		6-Inch		7 Inch		8 Inch	
Velocity	Capacity	Friction	Capacity	Friction	Capacity	Friction	Capacity	Friction	Capacity	Friction	Capacity	Friction
300	110	3.11	195	2.56	306	2.05	410	1.70	600	1.46	783	1.28
480	176	8.16	314	6.12	490	4.9	705	4.08	959	3.19	1,253	3.06
540	198	10.1	352	7.61	550	6.11	791	5.09	1,079	4.36	1,110	3.82

against which they are operated, have a good efficiency. A pump of this type, with a direct-connected engine, is shown in Fig. 111.

Under ordinary conditions the efficiency of a centrifugal pump falls off considerably for heads above 30 or 35 feet; but special high-speed pumps are constructed which work with a good efficiency against 500 feet or more.

Under favorable conditions an efficiency of 60 to 70 per cent is often obtained; but for hot-water circulation it is more common to assume an efficiency of about 50 per cent for the average case.

The horse-power required for driving a pump is given by the following formula:

$$\text{H. P.} = \frac{H \times V \times 8.3}{33{,}000 \times E},$$

in which

H = Friction head in feet;
V = Gallons of water delivered per minute;
E = Efficiency of pump.

Centrifugal pumps are made in many sizes and with varying proportions, to meet the different requirements of capacity and head.

Heaters. If the water is heated in a boiler, any good form may be used, the same as for gravity work. In case tubular boilers are used, the entire shell may be filled with tubes, as no steam space is required.

In order to prevent the water from passing in a direct line from the inlet to the outlet, a series of baffle-plates should be used to bring it in contact with all parts of the heating surface.

When steam is used for heating the water, it is customary to employ a closed feed-water heater with the steam on the inside of the tubes and the water on the outside.

Any good form of heater can be used for this purpose by providing it with steam connections of sufficient size. In the ordinary form of heater, the feed-water flows through the tubes, and the connections are therefore small, making it necessary to substitute special nozzles of large size when used in the manner here described.

When computing the required amount of heating surface in the tubes of a heater, it is customary to assume an efficiency of about 200 B. T. U. per square foot of surface per hour, per degree difference in emperature between the water and steam.

It is usual to circulate the water at a somewhat higher temperature in systems of this kind, and a maximum initial temperature of 200 degrees, with a drop of 40 degrees in the heating system, may be used in computing the size of heater. If exhaust steam is used at atmospheric pressure, there will be a difference of 212 − 180 = 32 degrees, between the *average* temperature of the water and the steam, giving an efficiency of 200 × 32 = 6,400 B. T. U. per square foot of heating surface.

From this it is evident that 6,400 ÷ 170 = 38 square feet of direct radiating surface, or 6,400 ÷ 400 = 16 square feet of indirect, may be supplied from each square foot of tube surface in the heater.

Example. A building having 6,000 square feet of direct, and 2,000 square feet of indirect radiation, is to be warmed by hot water under forced circulation. Steam at atmospheric pressure is to be used for heating the water. How many square feet of heating surface should the heater contain?

6,000 ÷ 38 = 158; and 2,000 ÷ 16 = 125; therefore, 158 + 125 = 283 square feet, the area of heating surface called for.

When the exhaust steam is not sufficient for the requirements, an auxiliary live steam heater is used in connection with it.

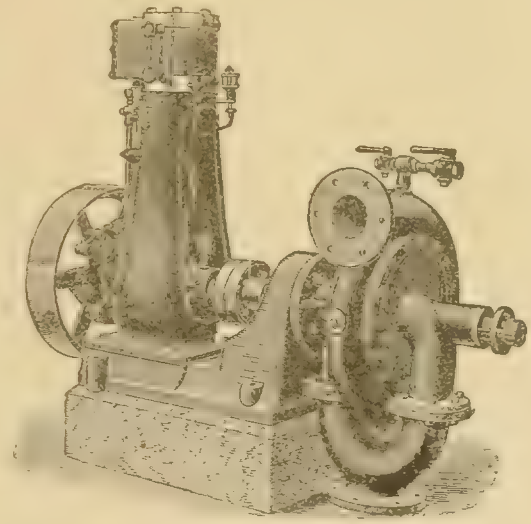


Fig. 111. Centrifugal Pump Direct-Connected to Engine, for Forced Hot-Water Circulation.

EXAMPLES FOR PRACTICE

1. A building contains 10,000 square feet of direct radiation and 4,000 square feet of indirect radiation. How many gallons of water must be circulated through the mains per minute, allowing a drop in temperature of 40 degrees? Ans. 165 gal.

2. In the above example, what size of main should be used, assuming the circuit to be 300 feet in length and to contain ten long-turn elbows? The friction head is not to exceed 10 ft., and the velocity of flow not to exceed 300 feet per minute. Ans. 4-inch.

3. What horse-power will be required to drive a centrifugal pump delivering 400 gallons per minute against a friction head of 40 feet, assuming an efficiency of 50 per cent for the pump?

Ans. 8 H. P.

4. A building contains 10,000 square feet of direct radiation and 5,000 square feet of indirect radiation. Steam at atmospheric pressure is to be used. The initial temperature of the water is to be 200°; and the final 160°. How many square feet of heating surface should the heater contain? Ans. 575 sq. ft.

5. How many square feet would be required in the above heater (Example 4) if the initial temperature of the water were 180° and the final temperature 150°? Ans. 399 sq. ft.

EXHAUST-STEAM HEATING

Steam, after being used in an engine, contains the greater part of its heat; and if not condensed or used for other purposes, it can usually be employed for heating without affecting to any great extent the power of the engine. In general, we may say that it is a matter of economy to use the exhaust for heating, although various factors must be considered in each case to determine to what extent this is true. The more important considerations bearing upon the matter are: the relative quantities of steam required for power and for heating; the length of the heating season; the type of engine used; the pressure carried; and, finally, whether the plant under consideration is entirely new, or whether, on the other hand, it involves the adapting of an old heating system to a new plant.

The first use to be made of the exhaust steam is the heating of the feed-water, as this effects a constant saving both summer and winter, and can be done without materially increasing the back-pressure on the engine. Under ordinary conditions, about one-sixth of the steam supplied to the engine can be used in this way, or more nearly one-fifth of the exhaust *discharged* from the engine.

We may assume in average practice that about 80 per cent of the steam supplied to an engine is discharged in the form of steam at a lower pressure, the remaining 20 per cent being partly converted into work and partly lost through cylinder condensation. Taking this into account, there remains, after deducting the steam used for feed-water heating, $.8 \times \frac{4}{5} = .64$ of the entire quantity of steam supplied to the engine, available for heating purposes.

When the quantity of steam required for heating is small compared with the total amount supplied to the engine, or where the heating season is short, it is often more economical to run the engine condensing and use the live steam for heating. This can be determined in any particular case by computing the saving in fuel by the use of a condenser, taking into account the interest and depreciation on the first cost of the condensing apparatus, and the cost of water, if it must be purchased, and comparing it with the cost of heating with live steam.

Usually, however, in the case of office buildings and institutions, and commonly in the case of shops and factories, especially in northerly latitudes, it is advantageous to use the exhaust for heating, even if a condenser is installed for summer use only. The principal objection raised to the use of exhaust steam has been the higher back-pressure required on the engines, resulting in a loss of power nearly proportional to the ratio of the back-pressure to the mean effective pressure. There are two ways of offsetting this loss—one, by raising the initial or boiler pressure; and the other, by increasing the cut-off of the engine. Engines are usually designed to work most economically at a given cut-off, so that in most cases it is undesirable to change it to any extent. Raising the boiler pressure, on the other hand, is not so objectionable if the increase amounts to only a few pounds.

Under ordinary conditions in the case of a simple engine, a rise of 3 pounds in the back-pressure calls for an increase of about 5 pounds in the boiler pressure, to maintain the same power at the engine.

The indicator card shows a back-pressure of about 2 pounds when an engine is exhausting into the atmosphere, so that an increase of 3 pounds would bring the pressure up to a total of 5 pounds which should be more than sufficient to circulate the steam through any well-designed heating system.

If it is desired to reduce rather than increase the back-pressure, one of the so-called *vacuum systems*, described later, can be used.

The systems of steam heating which have been described are those in which the water of condensation flows back into the boiler by gravity. Where exhaust steam is used, the pressure is much below that of the boiler, and it must be returned either by a pump or by a return trap. The exhaust steam is often insufficient to supply the entire heating system, and must be supplemented by live steam taken directly from the boiler. This must first pass through a reducing valve in order to reduce the pressure to correspond with that carried in the heating system.

An engine does not deliver steam continuously, but at regular intervals, at the end of each stroke; and the amount is likely to vary with the work done, since the governor is adjusted to admit steam in such a quantity as is required to maintain a uniform speed. If the work is light, very little steam will be admitted to the engine; and for this reason the supply available for heating may vary somewhat, depending upon the use made of the power delivered by the engine. In mills the amount of exhaust steam is practically constant; in office buildings where power is used for lighting, the variation is greater, especially if power is also required for the running of elevators.

The general requirements for a successful system of exhaust steam heating include a system of piping of such proportions that only a slight increase in back-pressure will be thrown upon the engine; a connection which shall automatically supply live steam at a reduced pressure as needed; provision for removing the oil from the exhaust steam; a relief or back-pressure valve arranged to prevent any sudden increase in back pressure on the engine; and a return system of some kind for returning the water of condensation to the boiler against a higher pressure. These requirements may be met in various ways, depending upon actual conditions found in different cases.

To prevent sudden changes in the back-pressure, due to irregular supply of steam, the exhaust pipe from the engine is often carried to a closed tank having a capacity from 30 to 40 times that of the engine cylinder. This tank may be provided with baffle-plates or other arrangements and may serve as a separator for removing the oil from the steam as it passes through.

Any system of piping may be used; but great care should be taken that as little resistance as possible is introduced at bends and fittings; and the mains and branches should be of ample size. Usually the best results are obtained from the system in which the main steam pipe is carried directly to the top of the building, the distributing pipes being run from that point, and the radiating surfaces supplied by a down-flowing current of steam.

Before taking up the matter of piping in detail a few of the more important pieces of apparatus will be described in a brief way.

Reducing Valves. The action of pressure-reducing valves has been taken up quite fully in "Boiler Accessories," and need not be repeated here. When the reduction in pressure is large, as in the case of a combined power and heating plant, the valve may be one or two sizes smaller than the low-pressure main into which it discharges. For example, a 5-inch valve will supply an 8-inch main, a 4-inch a 6-inch main, a 3-inch a 5-inch main, a 2½-inch a 4-inch main, etc.

For the smaller sizes, the difference should not be more than one size. All reducing valves should be provided with a valved by-pass for cutting out the valve in case of repairs. This connection is usually made as shown in plan by Fig. 112.

Grease Extractor. When exhaust steam is used for heating purposes, it must first be passed through some form of separator for removing the oil; and as an additional precaution it is well to pass the water of condensation through a separating tank before returning it to the boilers.

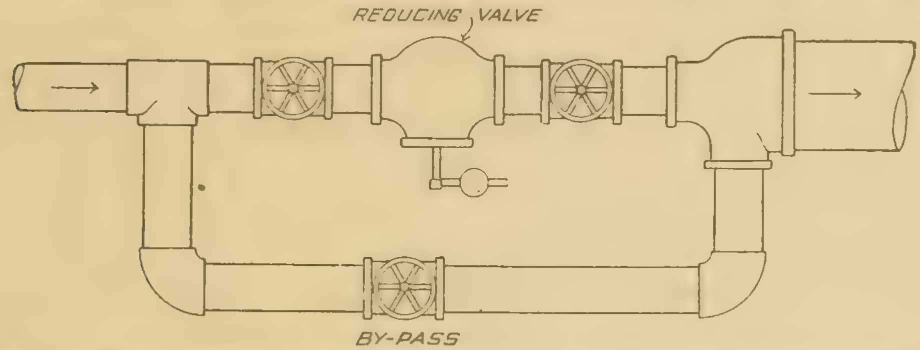


Fig. 112. Connections of Reducing Valve in Exhaust-Steam Heating System.

Such an arrangement is shown in Fig. 113. As the oil collects on the surface of the water in the tank, it can be made to overflow into the sewer by closing the valve in the connection with the receiving tank, for a short time.

As much of the oil as possible should be removed before the steam enters the pipes and radiators, else a coating will be formed on their inner surfaces, which will reduce their heating efficiency. The separation of the oil is usually effected by introducing a series of baffling plates in the path of the steam; the particles of oil striking these are stopped, and thus separated from the steam. The oil drops into a receiver provided for this purpose and is discharged through a trap to the sewer.

In the separator, or extractor, shown in Fig. 114, the separation is accomplished by a series of plates placed in a vertical position in the body of the separator, through which the steam must pass. These plates consist of upright hollow columns, with openings at regular intervals for the admission of water and oil, which drain downward to the receiver below. The steam takes a zigzag course, and all of it comes in contact with the intercepting plates, which insures a thorough separation of the oil and other solid matter from the steam. Another form, shown in Fig. 115, gives excellent results, and has the advantage of providing an equalizing chamber for overcoming, to some extent, the unequal pressure due to the varying load on the engine. It consists of a tank or receiver about 4 feet in diameter, with heavy boiler-iron heads slightly crowned to give stiffness.

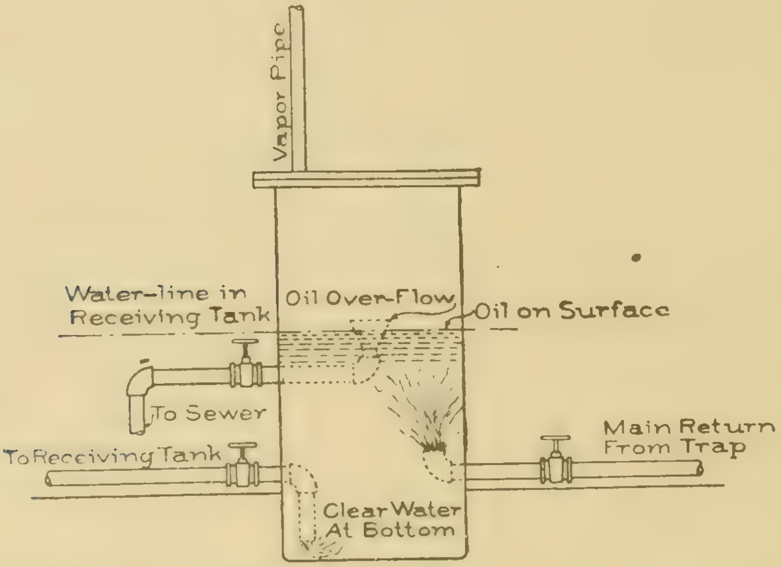


Fig. 113. Separator for Removing Oil from Exhaust Steam and Water Condensation.

Through the center is a layer of excelsior (wooden shavings of long fibre) about 12 inches in thickness, supported on an iron grating, with a similar grating laid over the top to hold it in place. The steam enters the space below the excelsior and passes upward, as shown by the arrows. The oil is caught by the excelsior, which can be renewed from time to time as it becomes saturated. The oil and water which fall to the bottom of the receiver are carried off through a trap. Live steam may be admitted through a reducing valve, for supplementing the exhaust when necessary.

Back=Pressure Valve. This is a form of relief valve which is placed in the outboard exhaust pipe to prevent the pressure in the heating system from rising above a given point. Its office is the

reverse of the reducing valve, which supplies more steam when the pressure becomes too low. The form shown in Fig. 116 is designed for a vertical pipe. The valve proper consists of two discs of unequal area, the combined area of which equals that of the pipe. The force tending to open the valve is that due to the steam pressure acting on an area equal to the difference in area between the two discs; it is clear from the cut that the pressure acting on the larger disc tends to open the valve while the pressure on the smaller acts in the opposite direction. The valve-stem is connected by a link and crank arm with a spindle upon which is a lever and weight outside. As the valve opens, the weight is raised, so that, by placing it in different positions on the lever arm, the valve will open at any desired pressure.

Fig. 117 shows a different type, in which a spring is used instead of a weight. This valve has a single disc moving in a vertical direction. The valve stem is in the form of a piston or dash-pot which prevents a too sudden movement and makes it more quiet in its action. The disc is held on its seat against the steam pressure by a lever attached to the spring as shown. When the pressure of the steam on the underside becomes greater than the tension of the spring, the valve lifts and allows the steam to escape. The tension of the spring can be varied by means of the adjusting screw at its upper end.

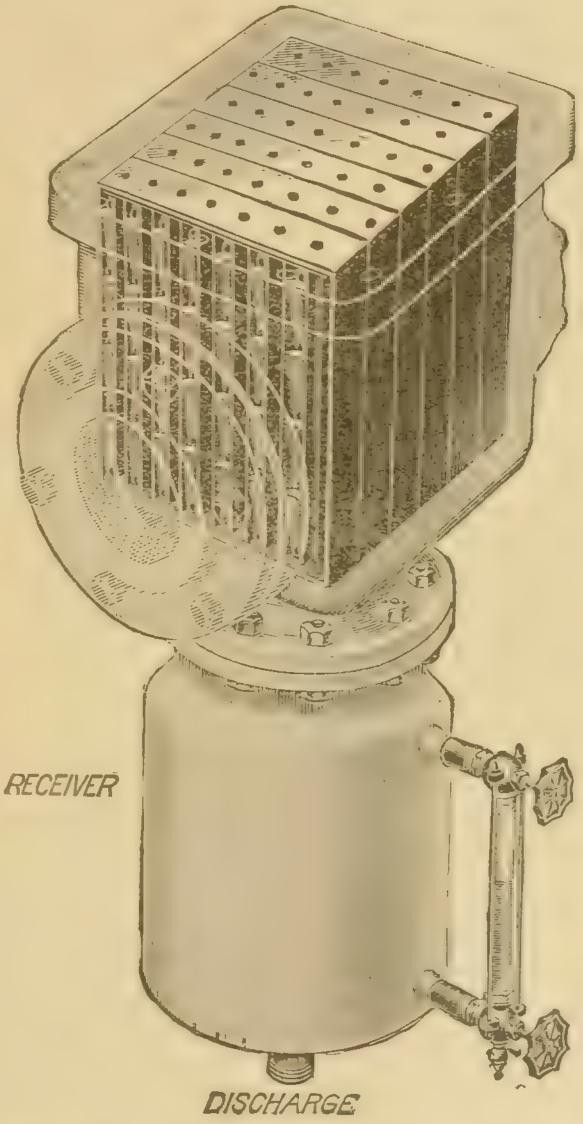


Fig. 114. Oil Separator Consisting of Vertical Plates with Openings Giving Steam a Zigzag Course.

A back-pressure valve is simply a low-pressure safety-valve designed with a specially large opening for the passage of steam through it. These valves are made for horizontal as well as for vertical pipes.

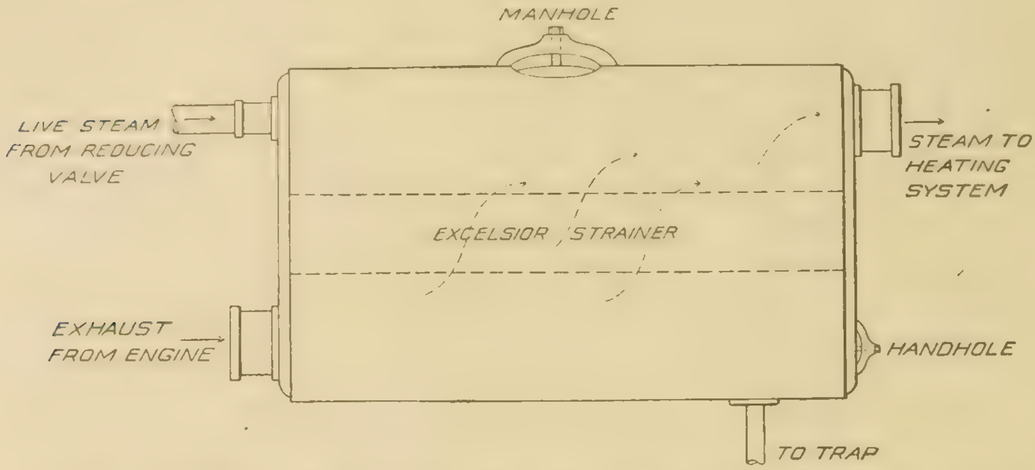


Fig. 115. Oil Separator Consisting of a Tank in which Steam is Filtered by Passing Upward through a Layer of Excelsior.

Exhaust Head. This is a form of separator placed at the top of an outboard exhaust pipe to prevent the water carried up in the steam from falling upon the roofs of buildings or in the street below. Fig. 118 is known as a centrifugal exhaust head. The steam, on entering at the bottom, is given a whirling or rotary motion by the spiral deflectors; and the water is thrown outward by centrifugal force against the sides of the chamber, from which it flows into the shallow trough at the base, and is carried away through the drip-pipe, which is brought down and connected with a drain-pipe inside the building. The passage of the steam outboard is shown by the arrows. Other forms are used in which the water is separated from the steam by deflectors which change the direction of the currents.

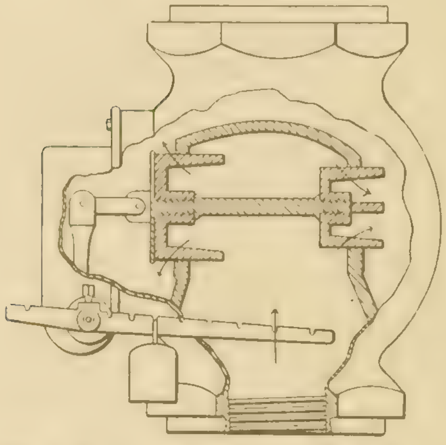


Fig. 116. Automatically Acting Back Pressure Valve Attached to Vertical Pipe. For Preventing Rise of Pressure in System above any Desired Point.

Automatic Return-Pumps. In exhaust heating plants, the condensation is returned to the boilers by means of some form of return-pump. A combined pump and receiver of the form illustrated in Fig. 119 is generally used. This consists of a cast-iron or wrought-iron tank mounted on a base in connection with a boiler feed-pump. Inside the tank is a ball-float connected by means of levers with a valve in the steam pipe which is connected with the pump. When the water-line in the tank rises above a certain level, the float is raised and opens the steam valve, which starts the pump. When the water is lowered to its normal level, the valve closes and the pump stops. By this arrangement, a constant water-line is maintained in the receiver, and the pump runs only as needed to care for the condensation as it returns from the heating system. If dry returns are used, they may be brought together and connected with the top of the receiver. If it is desired to seal the horizontal runs, as is usually the case, the receiver may be raised to a height sufficient to give the required elevation and the returns connected near the bottom below the water-line.

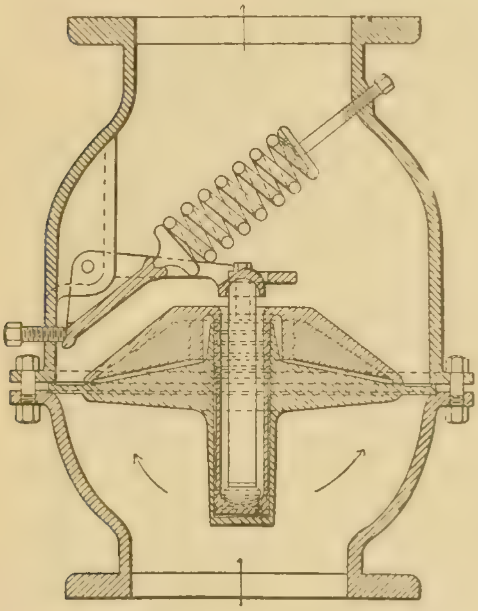


Fig. 117. Back-Pressure Valve Automatically Operated by a Spring.

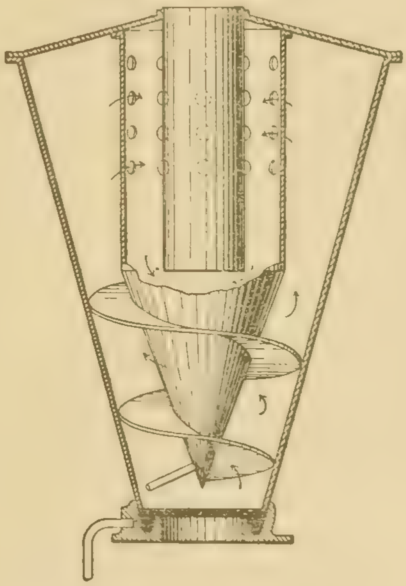


Fig. 118. Centrifugal Exhaust Head.

A *balance-pipe*, so called, should connect the heating main with the top of the tank, for equalizing the pressure; otherwise the steam above the water would condense, and the vacuum thus formed would draw all the water into the tank, leaving the returns practically empty and thus destroying the condition sought. Sometimes an independent regulator or pump governor is used in place of a receiver. One type is shown in Fig. 120. The return main is connected at the upper opening, and the pump suction at the lower. A float inside the chamber operates the steam valve shown at the top, and the pump works automatically as in the case just described.

If it is desired to raise the water-line, the regulator may be elevated to the desired height and connections made as shown in Fig. 121.

Return Traps. The principle of the return trap has been described in "Boiler Accessories," but its practical form and application will be taken up here. The type shown in Fig. 122 has all its working parts outside the trap. It consists of a cast-iron bowl pivoted at *G* and *H*. There is an opening through *G* connecting with the inside of the bowl. The pipe *K* connects through *C* with an interior pipe opening near the top (see Fig. 123). The pipe *D* connects with a receiver, into which all the returns are brought. *A* is a check-valve allowing water to pass through in the direction shown by the arrow. *E* is a pipe connecting with the boiler below the water-line. *B* is a

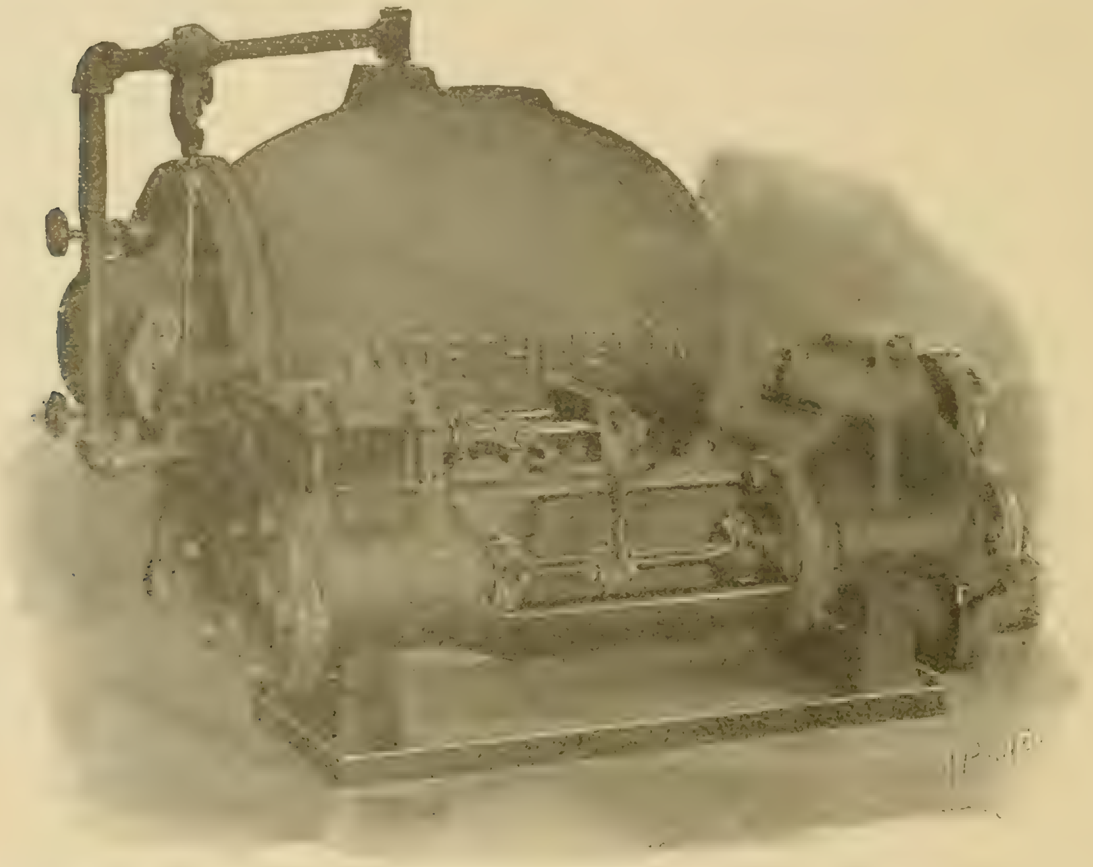


Fig. 119. Combined Receiver and Automatic Pump for Returning Water of Condensation to Boiler.

check opening toward the boiler, and *K*, a pipe connected with the steam main or drum.

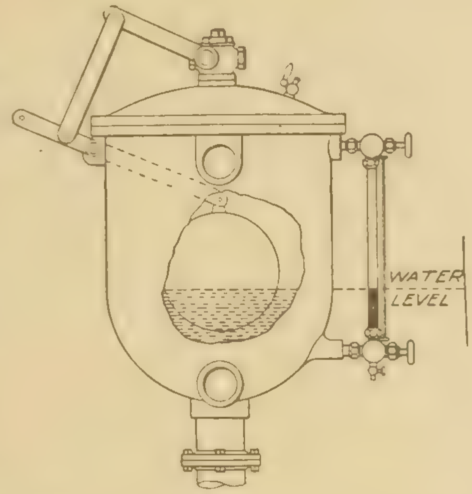


Fig. 120. Automatic Float-Operated Pump Governor Used instead of a Receiver.

The action of the trap is as follows: As the bowl fills with water from the receiver, it overbalances the weighted lever and drops to the bottom of the ring. This opens the valve *C*, and admits steam at boiler pressure to the top of the trap. Being at a higher level the water flows by gravity into the boiler, through the pipe *E*. Water and steam are kept from passing out through *D* by the check *A*.

When the trap has emptied itself, the weight of the ball raises it to the original position, which movement closes the valve *C* and opens the small vent *F*. The pressure in the bowl being relieved, water flows in from the receiver through *D*, until the trap is filled, when the process is repeated. In order to work satisfactorily, the trap should be placed at least 3 feet above the water-level in the boiler, and the

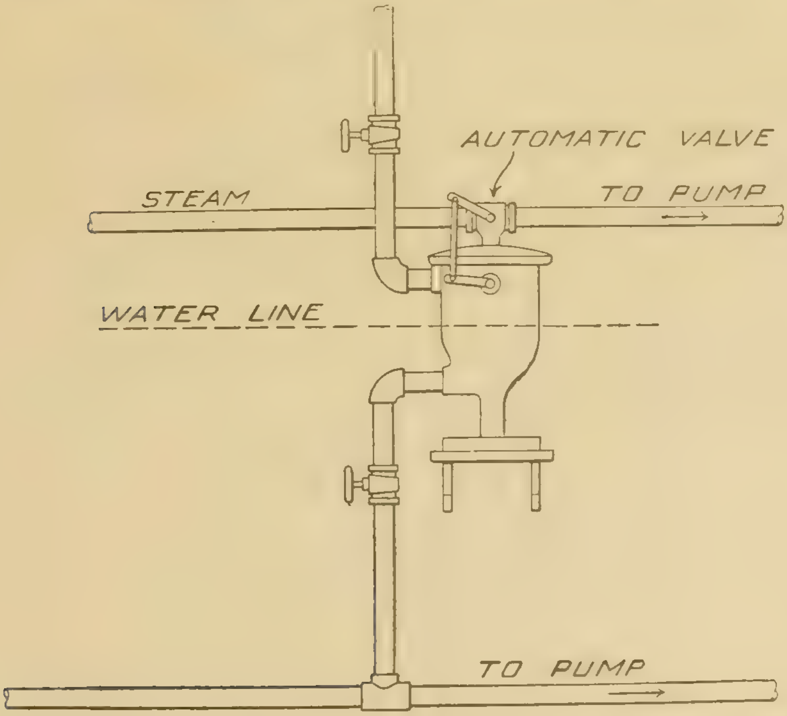


Fig. 121. Pump Regulator Placed at Sufficient Height to Raise Water-Line to Point Desired.

pressure in the returns must always be sufficient to raise the water from the receiver to the trap against atmospheric pressure, which is theoretically about 1 pound for every 2 feet in height. In practice there will be more or less friction to overcome, and suitable adjustments must be made for each particular case.

Fig. 124 shows another form of trap acting upon the same principle, except that in this case the steam valve is operated by a bucket or float inside the trap. The pipe connections are practically the same as with the trap just described.

Return traps are more commonly used in smaller plants where it is desired to avoid the expense and care of a pump.

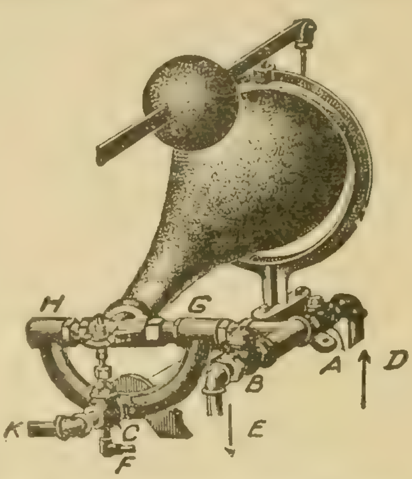


Fig. 122. Return Trap with Working Parts External.

Damper-Regulators. Every heating and every power plant should be provided with automatic means for closing the dampers when the steam pressure reaches a certain point, and for opening them again when the pressure drops. There are various regulators designed for this purpose, a simple form of which is shown in Fig. 125.

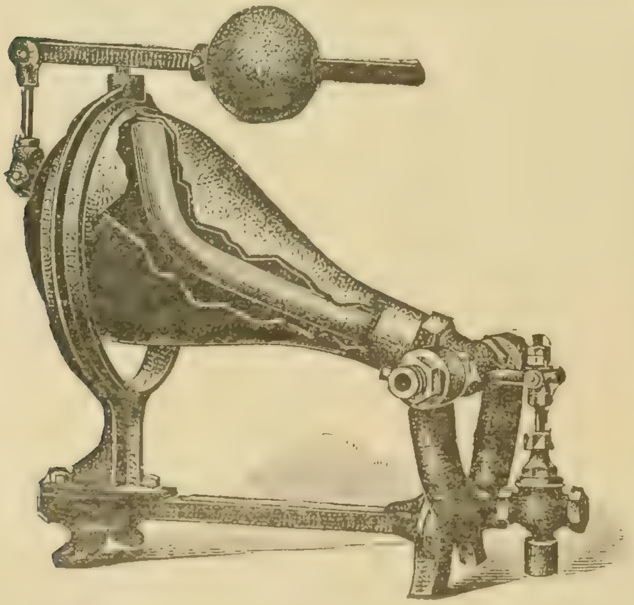


Fig. 123. Showing Interior Detail of Return Trap of Fig. 122.

Steam at boiler pressure is admitted beneath a diaphragm which is balanced by a weighted lever. When the pressure rises to a certain point, it raises the lever slightly and opens a valve which admits water under pressure above a diaphragm located near the smoke-pipe. This action forces down a lever connected by chains with the damper, and closes it. When the steam pressure drops, the water-valve is closed, and the different parts of the apparatus take their original positions.

Another form similar in principle is shown in Fig. 126. In this case a piston is operated by the water-pressure, instead of a diaphragm. In both types the pressures at which the damper shall open and close are regulated by suitable adjustments of the weights upon the levers.

Pipe Connections. The method of making the pipe connections in any particular case will depend upon the general arrangement of the apparatus and the various conditions. Fig. 127 illustrates the general principles to be followed, and by suitable changes may be used as a guide in the design of new systems.

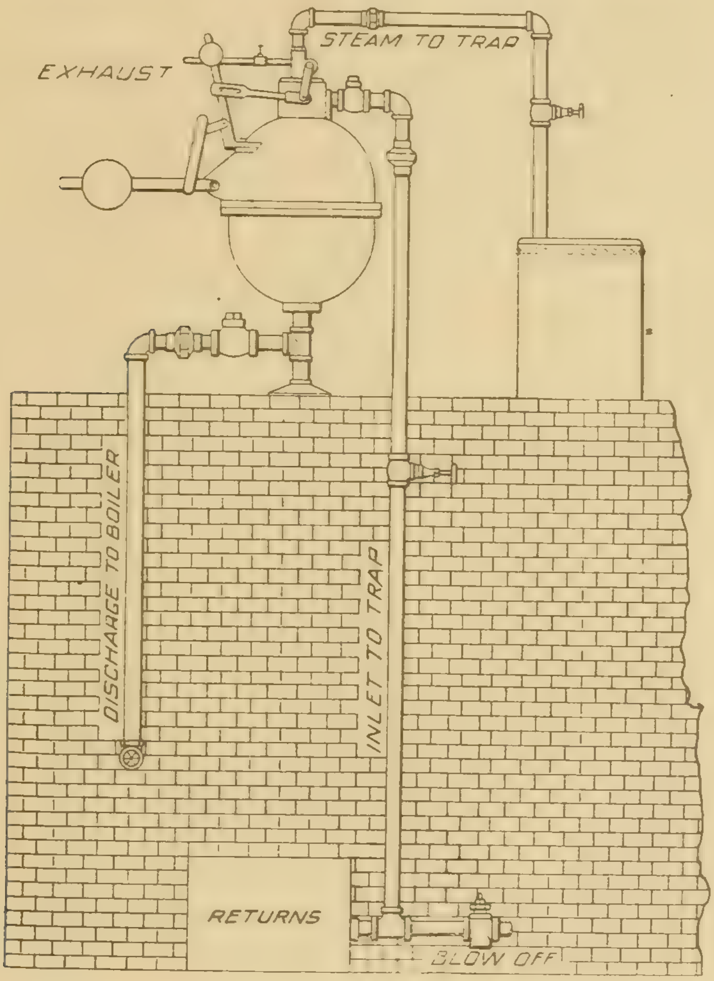


Fig. 124. Return Trap with Steam Valve Operated by Bucket or Float Inside.

Steam first passes from the boilers into a large drum or header. From this, a main, provided with a shut-off valve, is taken as shown; one branch is carried to the engines, while another is connected with the heating system through a reducing valve having a by-pass and cut-out valves. The exhaust from the engines connects with the large main over the boilers at a point just above the steam drum. The branch at the right is carried outboard through a back-pressure valve which may be set to carry any desired pressure on the system. The other branch at the left passes through an oil separator into the heating system. The connections between the mains and radiators are made in the usual way, and the main return is carried back to the return pump near the floor. A false water-line or seal is obtained by elevating the pump regulator as already described. An equalizing or balance pipe connects the top of the regulator with the low-pressure heating main, and high pressure is supplied to the pump as shown.

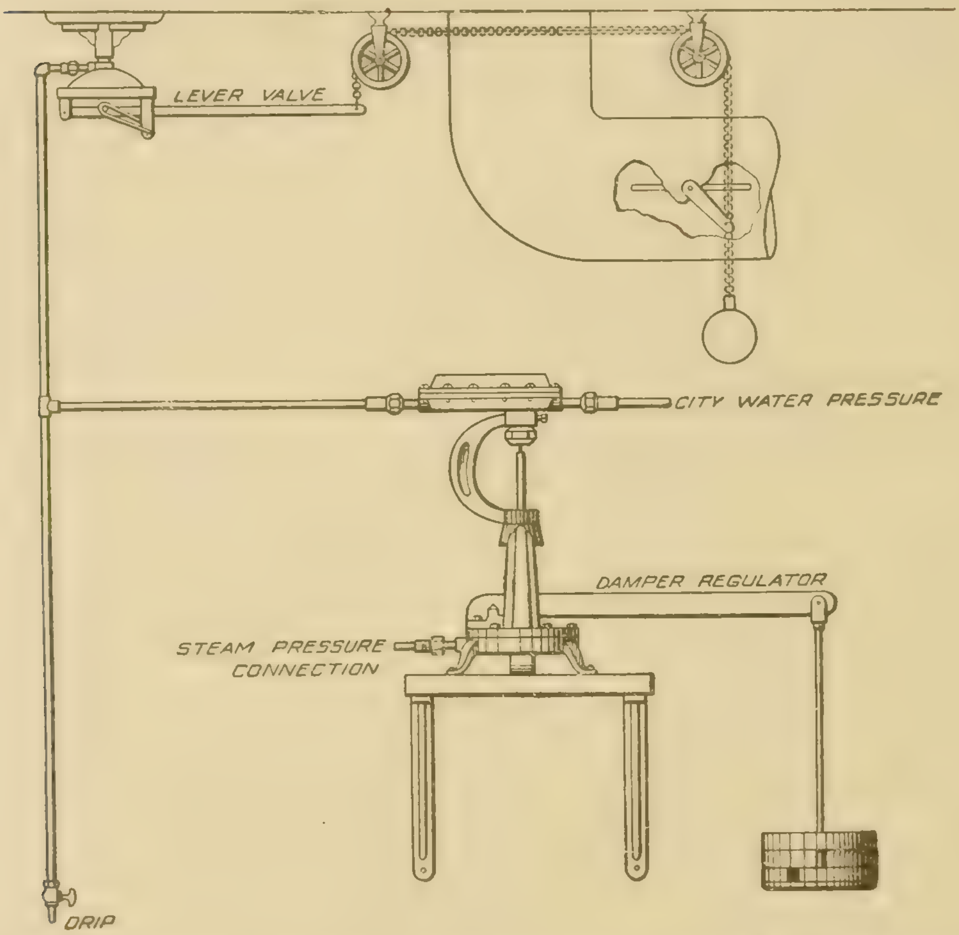


Fig. 125. Simple Form of Automatic Damper Regulator, Operated by Lever Attached to Diaphragm, for Closing Dampers when Steam Pressure Reaches a Certain Point.

A sight-feed lubricator should be placed in this pipe above the automatic valve; and a valved by-pass should be placed around the regulator, for running the pump in case of accident or repairs. The oil separator should be drained through a special oil trap to a catch-basin or to the sewer; and the steam drum or any other low points or pockets in the high-pressure piping should be dripped to the return tank through suitable traps.

Means should be provided for draining all parts of the system to the sewer, and all traps and special apparatus should be by-passed. The return-pump should always be duplicated in a plant of any size, as a safeguard against accident; and the two pumps should be run alternately, to make sure that one is always in working order.

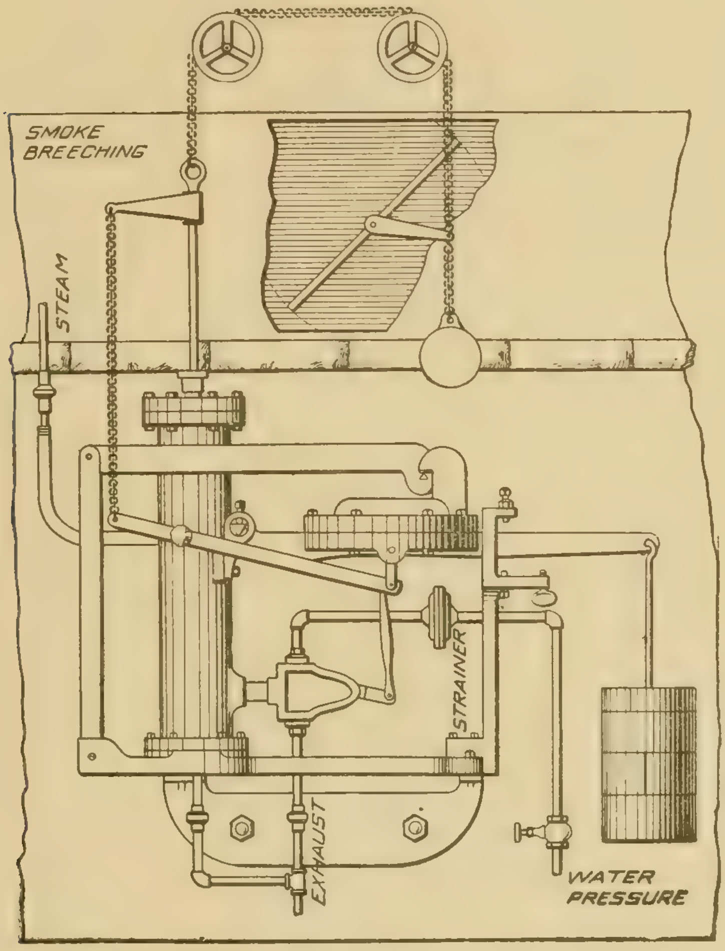


Fig. 126. Automatic Damper-Regulator Operated by Piston Actuated by Water-Pressure.

One piece of apparatus not shown in Fig. 127 is the feed-water heater. If all of the exhaust steam can be utilized for heating purposes, this is not necessary, as the cold water for feeding the boilers may be discharged into the return pipe and be pumped in with the condensation. In summertime, however, when the heating plant is not in use, a feed-water heater is necessary, as a large amount of heat

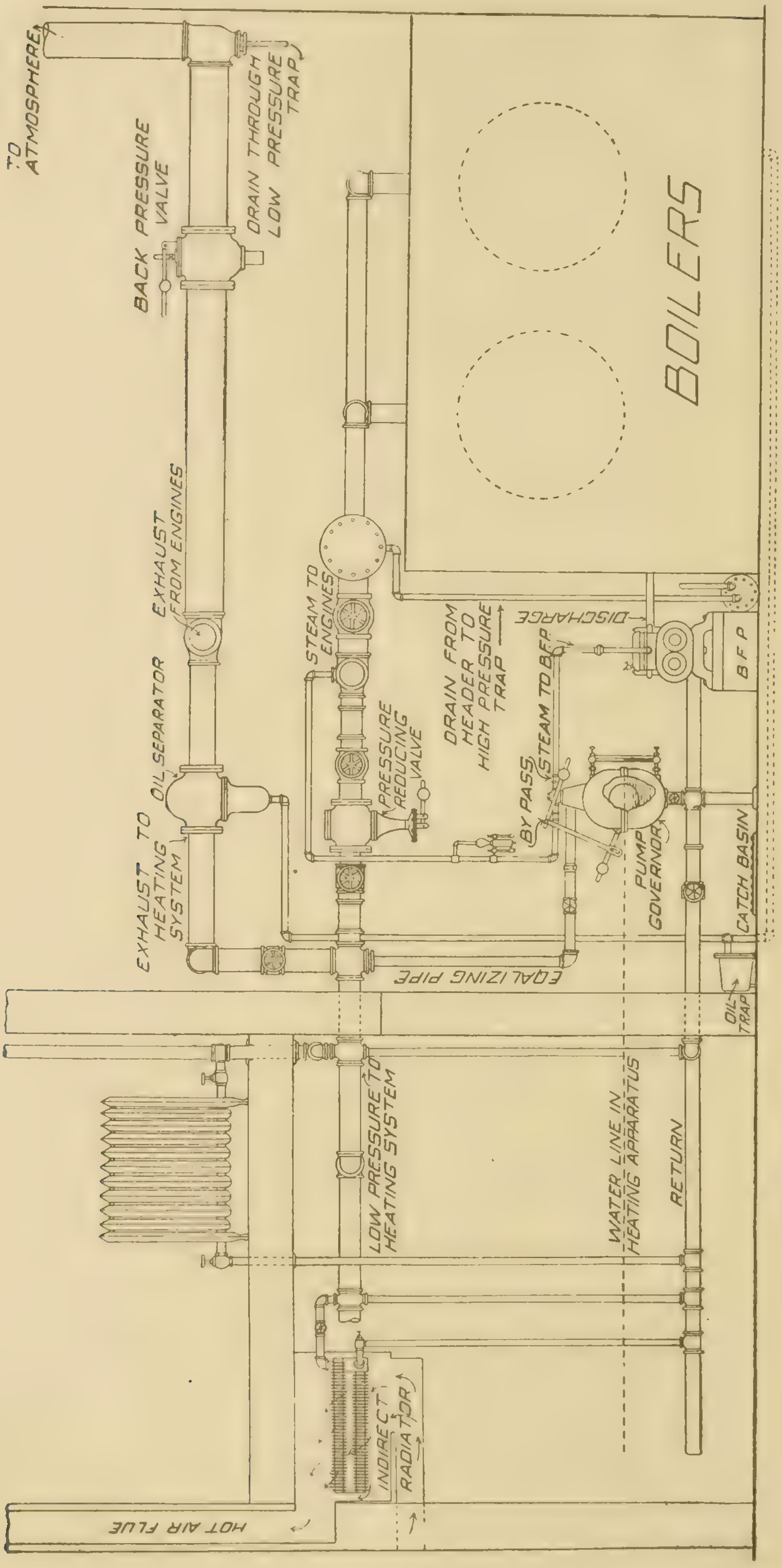
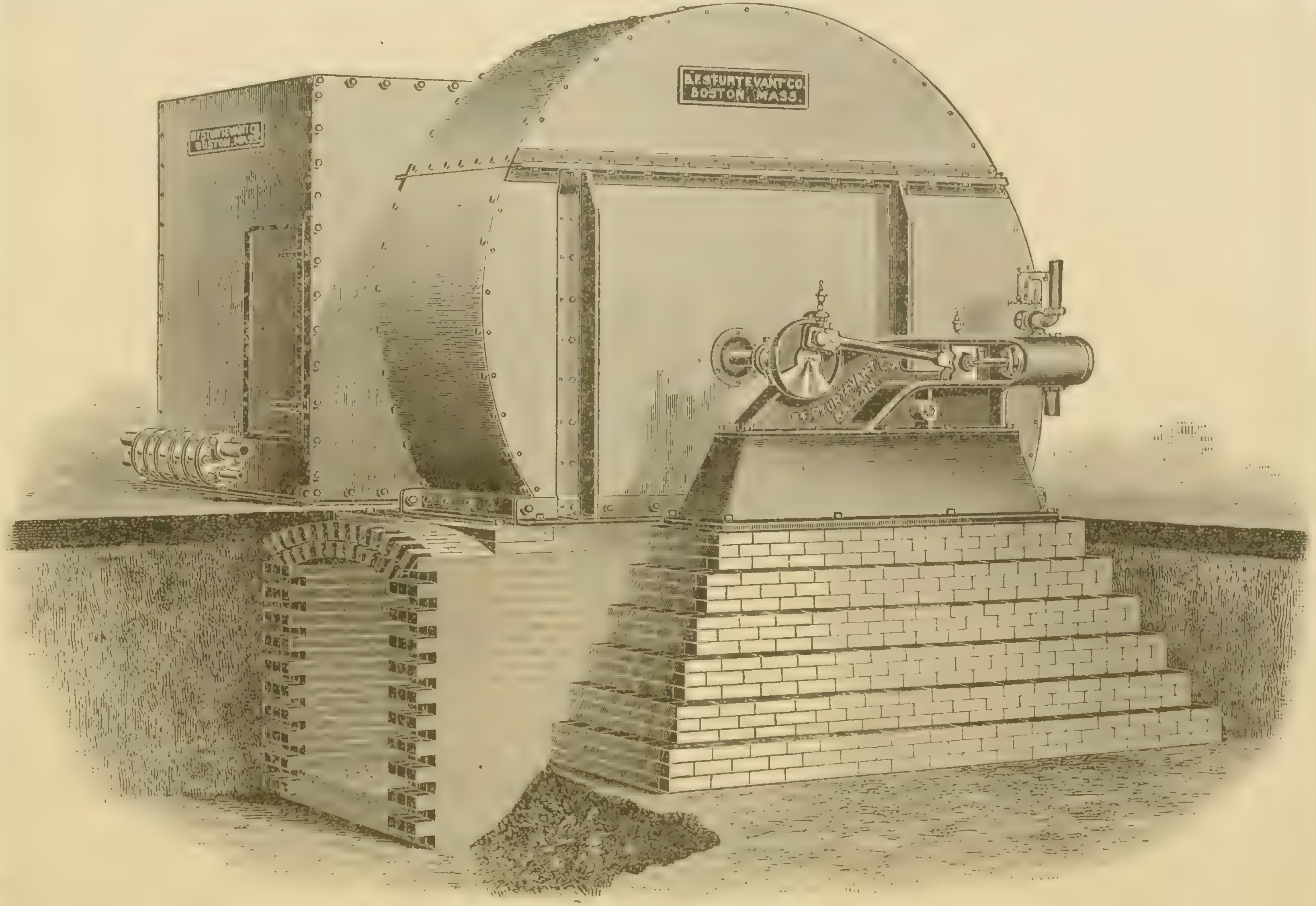


Fig. 127. General Method of Making Pipe Connections for Exhaust-Steam Heating.

which would otherwise be wasted may be saved in this way. The connections will depend somewhat upon the form of heater used, but in general a single connection with the heating main inside the back-pressure valve is all that is necessary. The condensation from the heater should be trapped to the sewer.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HEATING AND VENTILATION

PART III

VACUUM SYSTEMS

Low-Pressure or Vacuum Systems. In the systems of steam heating which have been described up to this point, the pressure carried has always been above that of the atmosphere, and the action of gravity has been depended upon to carry the water of condensation back to the boiler or receiver; the air in the radiators has been forced out through air-valves by the pressure of steam back of it. Methods will now be taken up in which the pressure in the heating system is less than the atmosphere, and where the circulation through the radiators is produced by suction rather than by pressure. Systems of this kind have several advantages over the ordinary methods of circulation under pressure. *First*—no back-pressure is produced at the engines when used in connection with exhaust steam; but rather there will be a reduction of pressure due to the partial vacuum existing in the radiators. *Second*—there is a complete removal of air from the coils and radiators, so that all portions are steam-filled and available for heating purposes. *Third*—there is complete drainage through the returns, especially those having long horizontal runs; and there is absence of water-hammer. *Fourth*—smaller return pipes may be used. The two older systems of this kind in common use are known as the Webster and Paul systems; other systems of recent introduction are described in the Instruction Paper on Steam and Hot-Water Fitting.

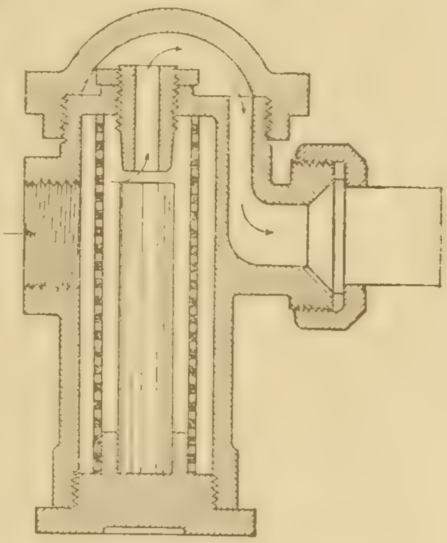


Fig. 128, Air Outlet-Valve for Radiator. Automatically Operated by Expansion and Contraction of Vulcanite Stem.

Webster System. This consists primarily of an automatic outlet-valve on each coil and radiator, connected with some form of suction apparatus such as a pump or ejector. One type of valve used is shown in section in Fig. 128, which replaces the usual hand-valve at the return end of the radiator. It is similar in construction to some of the air-valves already described, consisting of a rubber or vulcanite stem closing against a valve opening when made to expand by the presence of steam. When water or air fills the valve, the stem contracts and allows it to be sucked out as shown by the arrows. A perforated metal strainer surrounds the stem or expansion piece, to prevent dirt and sediment from clogging the valve.

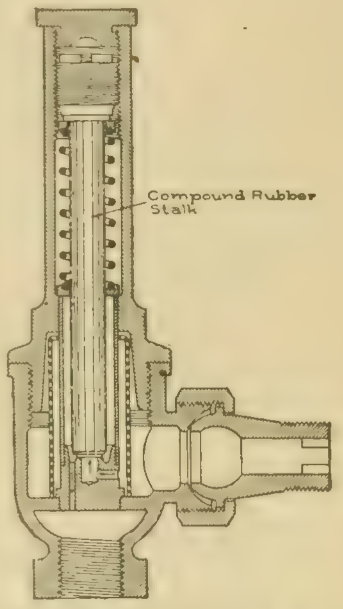


Fig. 129. Thermostat Attached to Angle-Valve with Top Removed.

Fig. 129 shows the valve—or *thermostat,* as it is called—attached to an ordinary angle-valve with the top removed; and Fig. 130 indicates the method of draining the bottoms of risers or the ends of mains.

Fig. 131 shows another form of this valve, called a *water-seal motor.* This is used under practically the same conditions as the one described above. Its action is as follows:

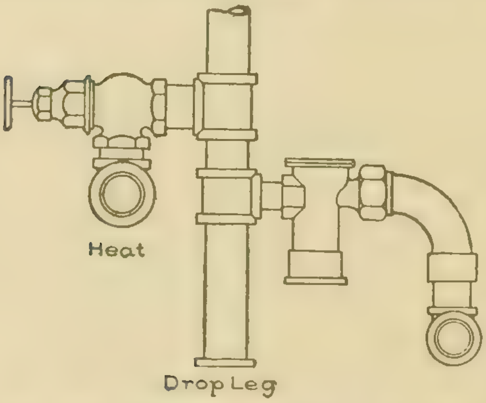


Fig. 130. Showing Method of Draining Bottoms of Risers or Ends of Mains.

Ordinarily, the seal *A* is down, and the central tube-valve is resting upon the seat, closing the port *K* and preventing direct communication between the interior of the motor-body *E* and the outlet *L*. The outlet is attached to a pipe leading to a vacuum-pump, or other draining apparatus, which exhausts the space *F* above the seal through the annular space between the spindle *B* and the inside of the central tube *G*. The water of condensation, accumulating in the radiator or coil, passes into the chamber *E*, through the inlet *C*, rises in the chamber, and seals the space between the seal-shell *A* and the sleeve of the bonnet *D*. The differential pressure thus created causes the seal *A* to rise, lifting the end of the central tube off the seat, thus opening a clear passageway for the ejection of the water of condensation.

When all the water of condensation has been drawn out of the radiator, the seal and tube are reseated by gravity, thus closing the port *K*, preventing waste or loss of steam; and the pressure is equalized above and below the seal because of the absence of water. This action is practically instantaneous. When the condensation is small in quantity, the discharge is intermittent and rapid.

The space between the seal *A* and the sleeve of the bonnet *D*, and the annular space between the central tube *G* and the spindle *B*, form a passageway through which the air is continually withdrawn by the vacuum pump or other draining apparatus.

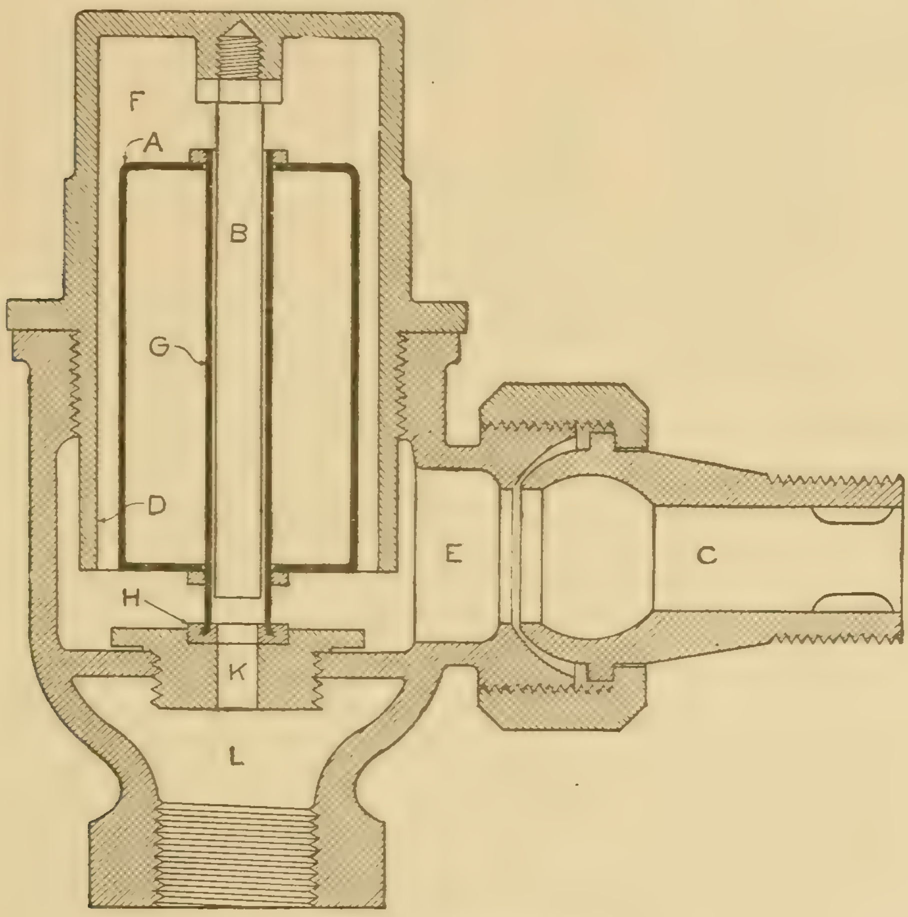


Fig. 131. Water-Seal Motor.

The action outlined continues as long as water is present.

No adjustment whatever is necessary; the motor is entirely automatic.

One special advantage claimed for this system is that the amount of steam admitted to the radiators may be regulated to suit the requirements of outside temperature; and is possible without water-

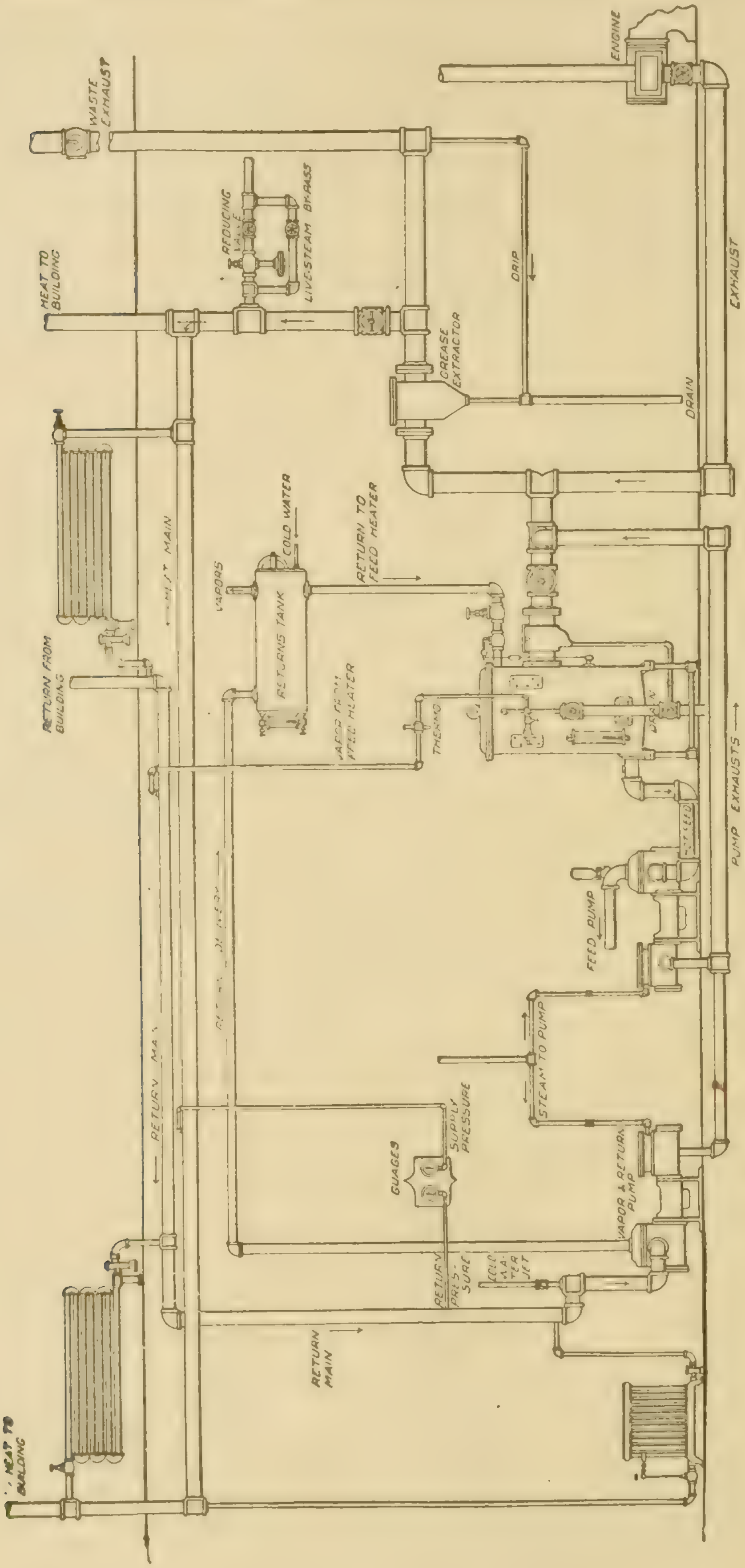
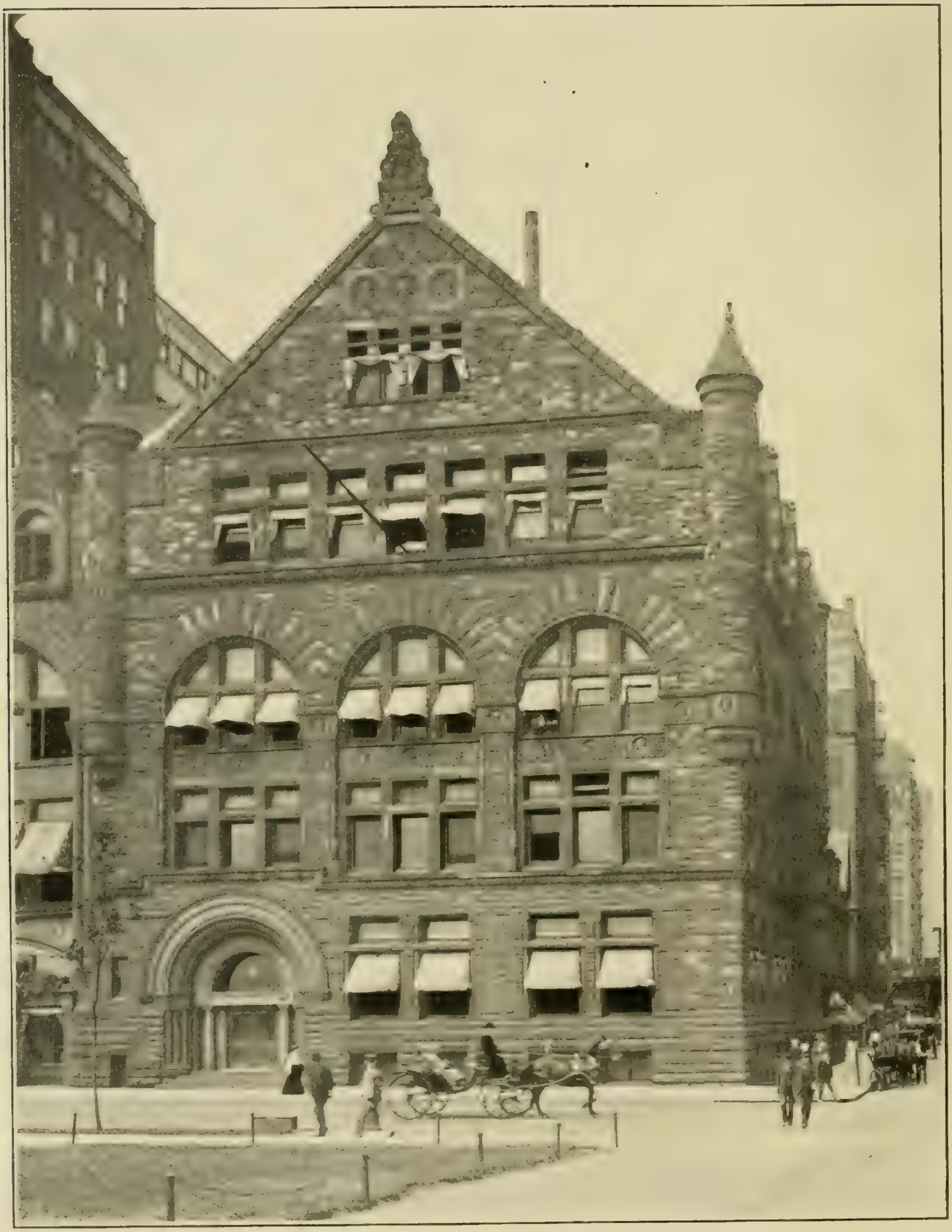


Fig. 132. Showing General Application of Webster System to Exhaust-Steam Heating.



CHICAGO CLUB, FORMERLY THE ART INSTITUTE OF CHICAGO

Burnham & Root, Architects.

Exterior of Brownstone. Built in 1888.

logging or hammering. This may be done at will by closing down on the inlet supply to the desired degree. The result is the admission of a smaller amount of steam to the radiator than it is calculated to condense normally. The condensation is removed as fast as formed, by the opening of the thermostatic valve.

The general application of this system to exhaust heating is shown in Fig. 132. Exhaust steam is brought from the engine as shown; one branch is connected with a feed-water heater, while the other is carried upward and through a grease extractor, where it branches again, one line leading outboard through a back-pressure valve and the other connecting with the heating main. A live steam connection is made through a reducing valve, as in the ordinary system. Valved connections are made with the coils and radiators in the usual manner; but the return valves are replaced by the special thermostatic valves described above.

The main return is brought down to a vacuum pump which discharges into a *return tank*, where the air is separated from the water and passes off through the vapor pipe at the top. The condensation then flows into the feed-water heater, from which it is automatically pumped back into the boilers. The cold-water feed supply is connected with the return tank, and a small cold-water jet is connected into the suction at the vacuum pump for increasing the vacuum in the heating system by the condensation of steam at this point.

Paul System. In this system the suction is connected with the air-valves instead of the returns, and the vacuum is produced by means of a steam ejector instead of a pump. The returns are carried back to a receiving tank, and pumped back to the boiler in the usual manner. The ejector in this case is called the *exhauster*.

Fig. 133 shows the general method of making the pipe connections with the radiators in this system; and Fig. 134, the details of connection at the exhauster.

A A are the returns from the air-valves, and connect with the exhausters as shown. Live steam is admitted in small quantities through the valves *B B*; and the mixture of air and steam is discharged outboard through the pipe *C*. *D D* are gauges showing the pressure in the system; and *E E* are check-valves. The advantage of this system depends principally upon the quick removal of air from the various radiators and pipes, which constitutes the principal obstruction to circulation; the inductive action in many cases is sufficient to cause the system to operate somewhat below atmospheric pressure.

Where exhaust steam is used for heating, the radiators should be somewhat increased in size, owing to the lower temperature of the steam. It is common practice to add from 20 to 30 per cent to the sizes required for low-pressure live steam.

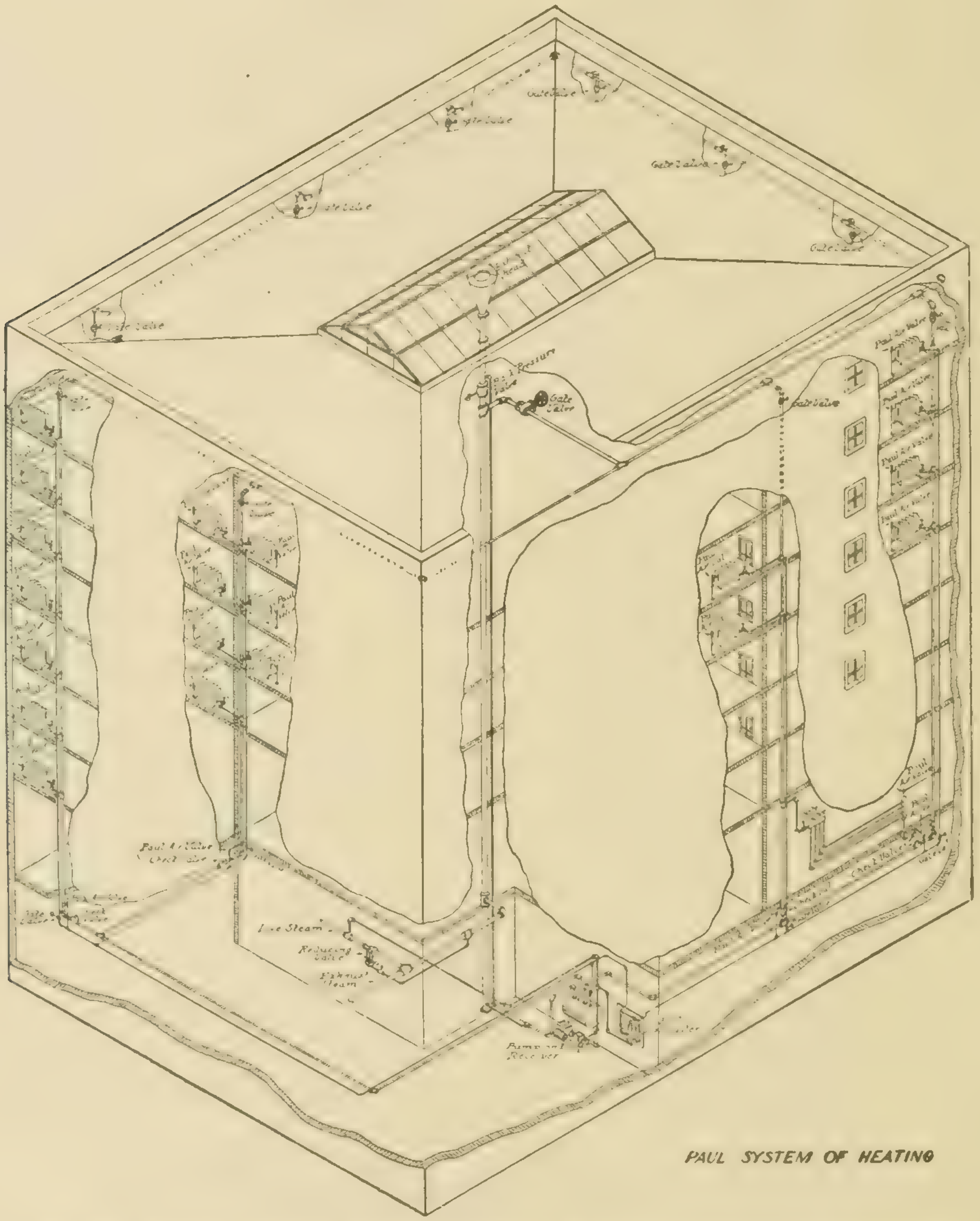


Fig. 133. Showing General Method of Making Pipe and Radiator Connections in Paul System.

FORCED BLAST

In a system of forced circulation by means of a fan or blower the action is positive and practically constant under all usual conditions of outside temperature and wind action. This gives it a decided advantage over natural or gravity methods, which are affected to a greater or less degree by changes in wind-pressure, and makes it especially adapted to the ventilation and warming of large buildings such as shops, factories, schools, churches, halls, theaters, etc., where large and definite air-quantities are required.

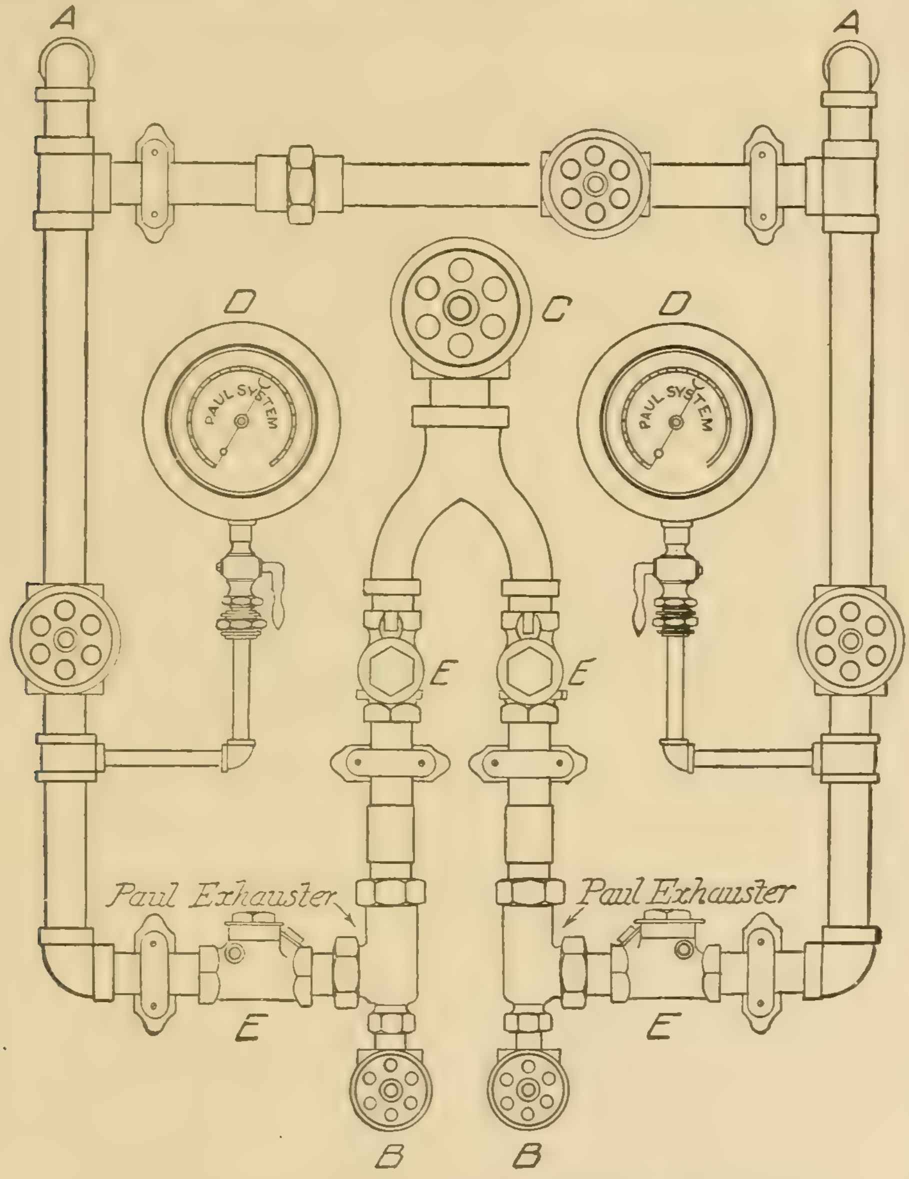


Fig. 134. Details of Connections at Exhauster, Paul System.

Exhaust Method. This consists in drawing the air out of a building, and providing for the heat thus carried away by placing steam coils under windows or in other positions where the inward leakage is supposed to be the greatest. When this method is used, a partial vacuum is created within the building or room, and all currents and leaks are inward; there is nothing to govern definitely the quality and place of introduction of the air, and it is difficult to provide suitable means for warming it.

Plenum Method. In this case the air is forced into the building, and its quality, temperature, and point of admission are completely under control. All spaces are filled with air under a slight pressure, and the leakage is outward, thus preventing the drawing of foul air into the room from any outside source. But above all, ample opportunity is given for properly warming the air by means of heaters, either in direct connection with the fan or in separate passages leading to the various rooms.

Form of Heating Surface. The best type of heater for any particular case will depend upon the volume and final temperature of the air, the steam pressure, and the available space. When the air is to be heated to a high temperature for both warming and ventilating a building, as in the case of a shop or mill, heaters of the general form shown in Figs. 135, 136, and 137 are used. These may also be adapted to all classes of work by varying the proportions as required. They can be made shallow and of large superficial area, for the comparatively low temperatures used in purely ventilating work; or deeper, with less height and breadth, as higher temperatures are required.

Fig. 135 shows in section a heater of this type, and illustrates the circulation of steam through it. It consists of sectional cast-iron bases with loops of wrought-iron pipe connected as shown. The steam enters the upper part of the bases or headers, and passes up one side of the loops, then across the top and down on the other side, where the condensation is taken off through the return drip, which is separated from the inlet by a partition. These heaters are made up in sections of 2 and 4 rows of pipes each. The height varies from $3\frac{1}{2}$ to 9 feet, and the width from 3 feet to 7 feet in the standard sizes. They are usually made up of 1-inch pipe, although $1\frac{1}{4}$-inch is commonly used in the larger sizes. Fig. 136 shows another form; in this case all the loops are made of practically the same length by the special form of construction shown. This is claimed to prevent the short-circuiting of steam through the shorter loops, which causes the outer pipes to remain cold. This form of heater is usually encased in a

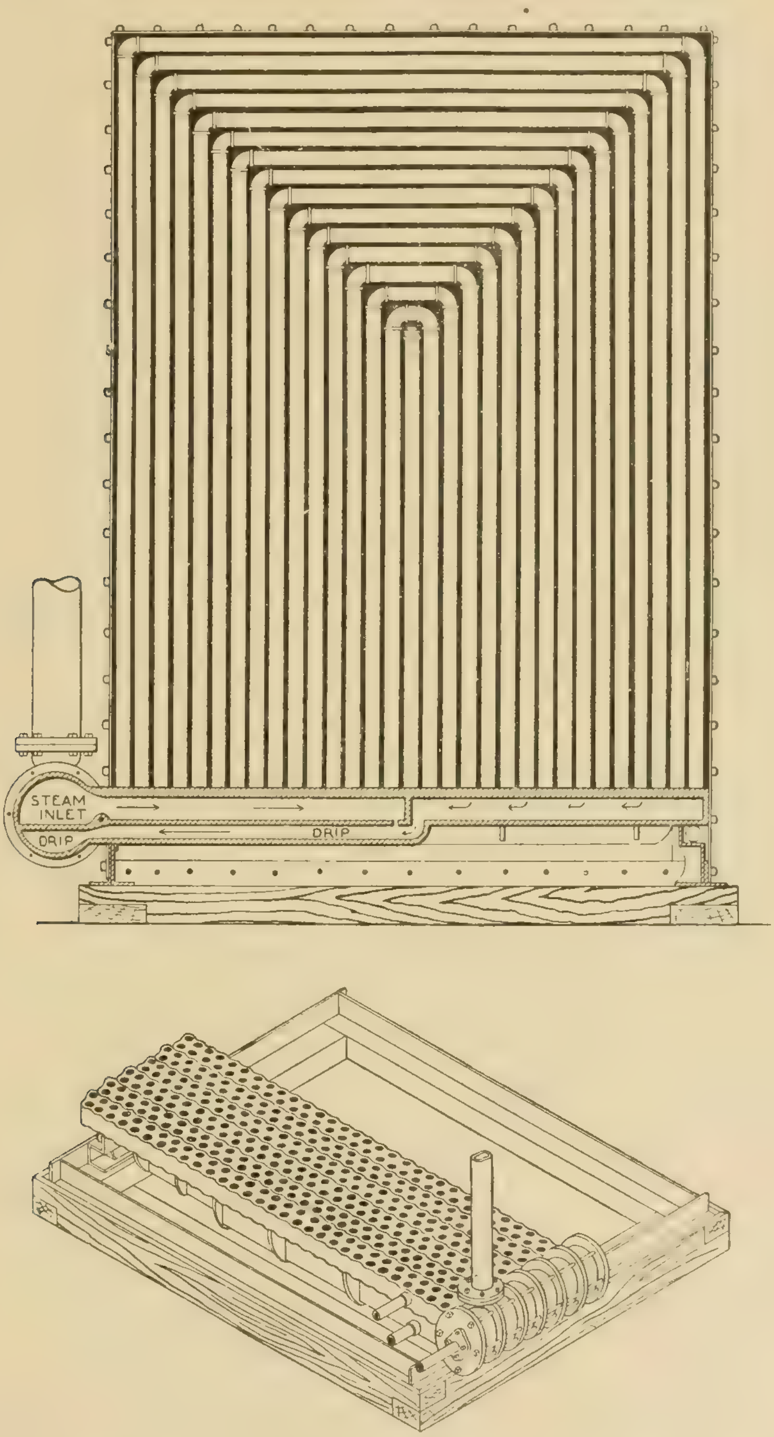


Fig. 135. Showing Circulation of Steam in Large Coil-Pipe Radiator for Heating Mills, Shops, etc.

sheet-steel housing as shown in Fig. 137, but may be supported on a foundation between brick walls if desired.

Fig. 138 shows a special form of heater particularly adapted to ventilating work where the air does not have to be raised above 70 or 80 degrees. It is made up of 1-inch wrought-iron pipe connected with supply and return headers; each section contains 14 pipes, and they are usually made up in groups of 5 sections each. These coils are supported upon tee-irons resting upon a brick foundation. Heat-

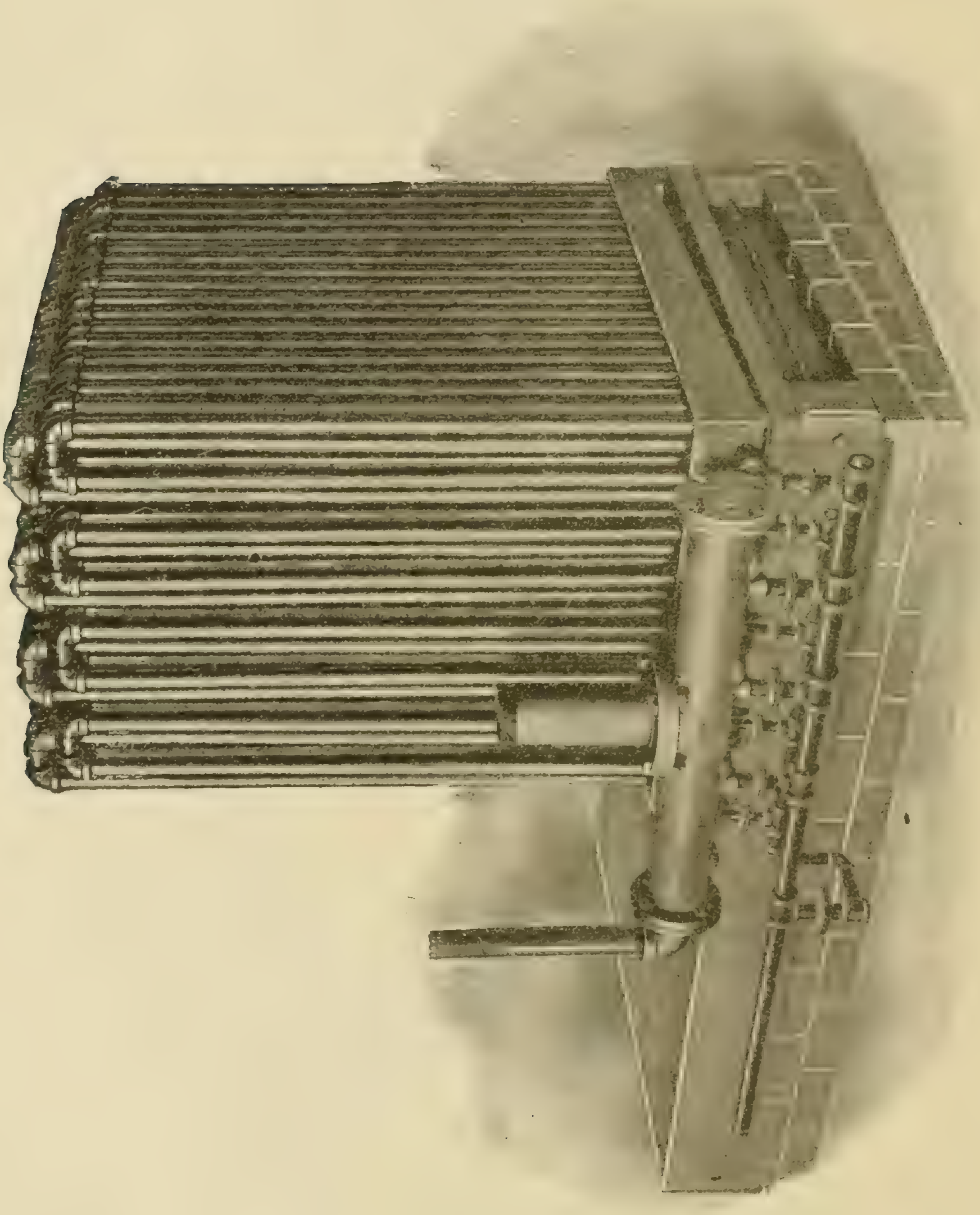


Fig. 136. Another Type of Large Coil Radiator for Mills, Factories, etc.

ers of this form are usually made to extend across the side of a room with brick walls at the sides, instead of being encased in steel housings.

Fig. 139 shows a front view of a cast-iron sectional heater for use under the same conditions as the pipe heaters already described. This heater is made up of several banks of sections, like the one shown in the cut, and enclosed in a steel-plate casing.

Cast-iron indirect radiators of the pin type are well adapted for use in connection with mechanical ventilation, and also for heating where the air-volume is large and the temperature not too high, as in churches and halls. They make a convenient form of heater for schoolhouse and similar work, for, being shallow, they can be supported upon I-beams at such an elevation that the condensation will be returned to the boilers by gravity.

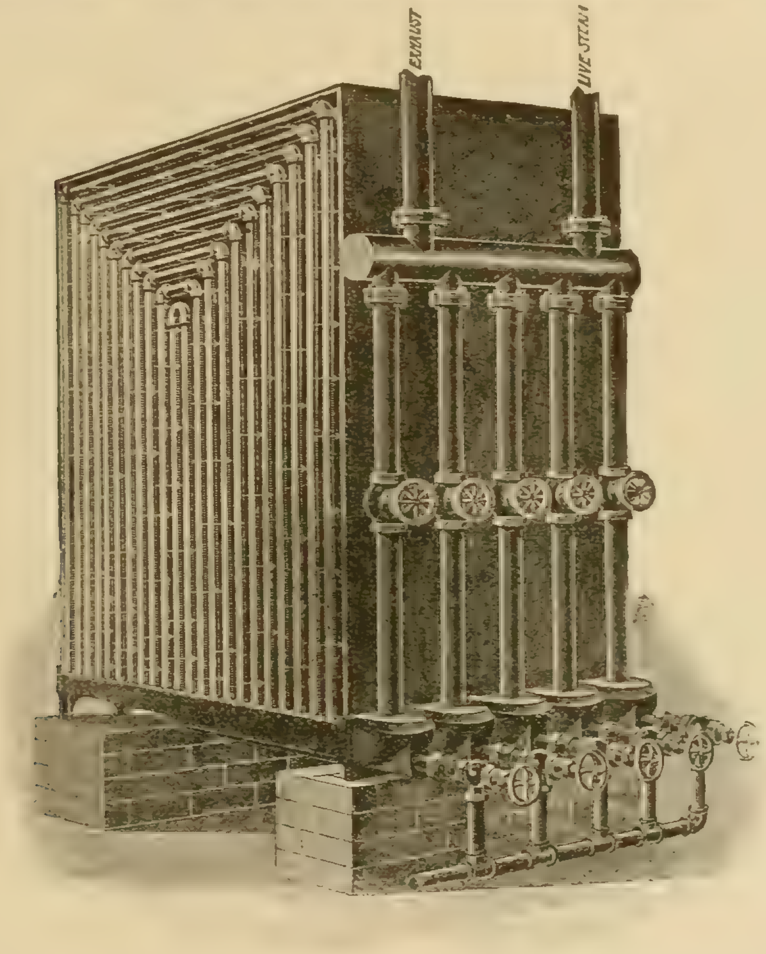
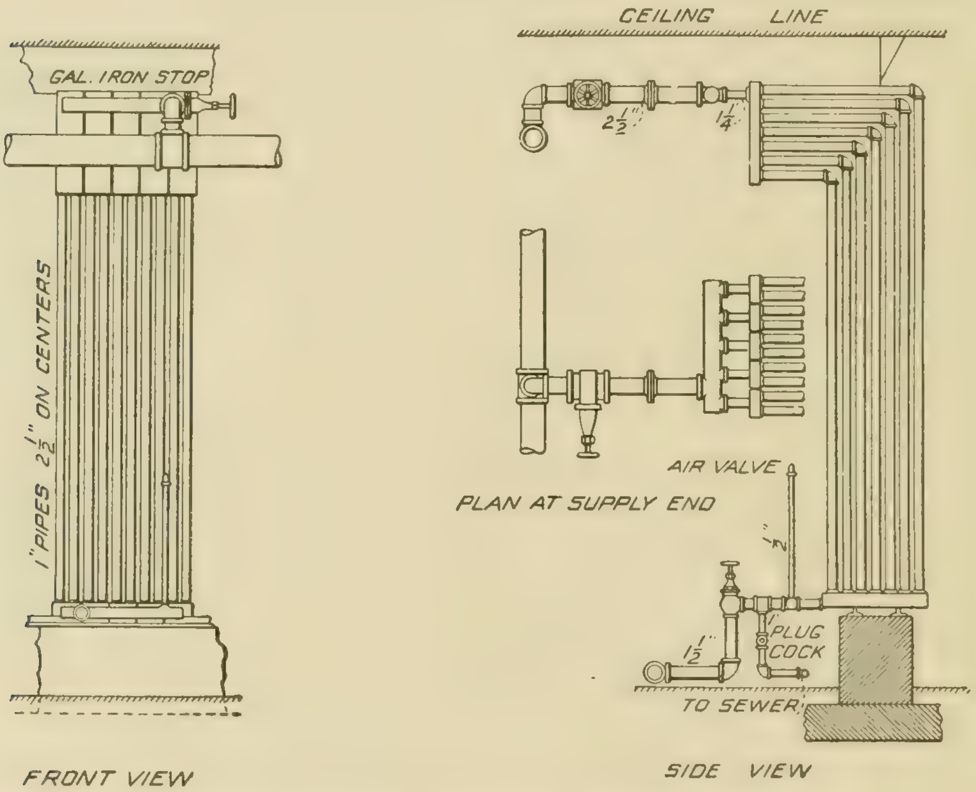


Fig. 137. Large Coil-Pipe Radiator Encased in Sheet-Steel Housing.

In the case of vertical pipe heaters, the bases are below the waterline of the boilers, and the condensation must be returned by the use of pumps and traps.

Efficiency of Pipe Heaters. The efficiency of the heaters used in connection with forced blast varies greatly, depending upon the temperature of the entering air, its velocity between the pipes, the temperature to which it is raised, and the steam pressure carried in the heater. The general method in which the heater is made up is also an important factor.

In designing a heater of this kind, care must be taken that the free area between the pipes is not contracted to such an extent that an excessive velocity will be required to pass the given quantity of air through it. In ordinary work it is customary to assume a velocity of 800 to 1,000 feet per minute; higher velocities call for a greater pressure on the fan, which is not desirable in ventilating work.



FRONT VIEW

SIDE VIEW

Fig. 138. Heater Especially Adapted to Ventilation where Air does not Have to be Heated above 70 to 80 degrees F.

In the heaters shown, about .4 of the total area is free for the passage of air; that is, a heater 5 feet wide and 6 feet high would have a total area of 5 × 6 = 30 square feet, and a free area between the pipes of 30 × .4 = 12 square feet. The depth or number of rows of pipe does not affect the free area, although the friction is increased and additional work is thrown upon the fan. The efficiency in any given heater will be increased by increasing the velocity of the air through it; but the final temperature will be diminished; that is, a larger quantity of air will be heated to a lower temperature in the second case, and, while the total heat given off is greater, the air-quantity increases more rapidly than the heat-quantity, which causes a drop in temperature.

Increasing the number of rows of pipe in a heater, with a constant air-quantity, increases the final temperature of the air, but diminishes the efficiency of the heater, because the average difference in temperature between the air and the steam is less. Increasing the steam pressure in the heater (and consequently its temperature) increases both the final temperature of the air and the efficiency of the heater. Table XXX has been prepared from different tests, and may be used as a guide in computing probable results under ordinary working conditions. In this table it is assumed that the air enters the heater at a temperature of zero and passes between the pipes with a velocity of 800 feet per minute. Column 1 gives the number of rows of pipe in the heater, ranging from 4 to 20 rows; and columns 2, 3, and 4, show the final temperature to which the entering air will be raised from zero under various pressures. Under 5 pounds pressure, for example, the rise in temperature ranges from 30 to 140 degrees; under 20 pounds, 35 to 150 degrees; and under 60 pounds, 45 to 170 degrees. Columns 5, 6, and 7 give approximately the corresponding efficiency of the heater. For example, air passing through a heater 10 pipes deep and carrying 20 pounds pressure, will be raised to a temperature of 90 degrees, and the heater will have an efficiency of 1,650 B. T. U. per square foot of surface per hour.

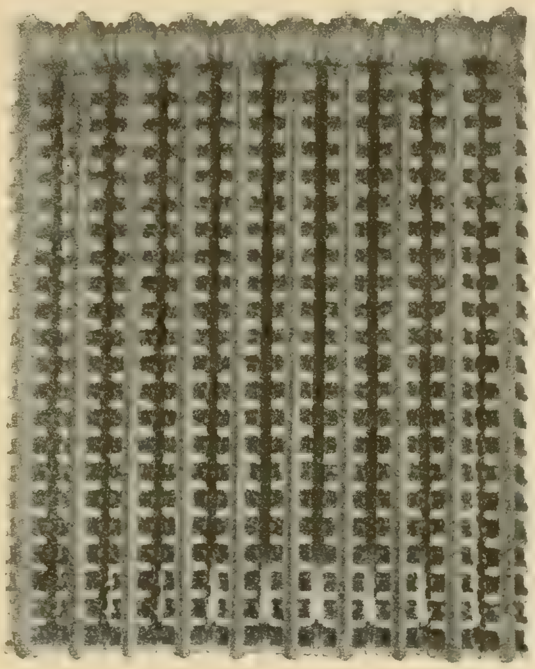


Fig. 139. Front View of Cast-Iron Sectional Heater. The Banks of Sections are Enclosed in a Steel-Plate Casing.

TABLE XXX

Data Concerning Pipe Heaters

Temperature of entering air, zero.—Velocity of air between the pipes, 800 feet per minute.

Rows of Pipe Deep	Temperature to which Air will be Raised from Zero			Efficiency of Heating Surface in B. T. U., per Square Foot per Hour		
	Steam Pressure in Heater			Steam Pressure in Heater		
	5 lbs.	20 lbs.	60 lbs.	5 lbs.	20 lbs.	60 lbs.
4	30	35	45	1,600	1,800	2,000
6	50	55	65	1,600	1,800	2,000
8	65	70	85	1,500	1,650	1,850
10	80	90	105	1,500	1,650	1,850
12	95	105	125	1,500	1,650	1,850
14	105	120	140	1,400	1,500	1,700
16	120	130	150	1,400	1,500	1,700
18	130	140	160	1,300	1,400	1,600
20	140	150	170	1,300	1,400	1,600

For a velocity of 1,000 feet, multiply the *temperatures* given in the table by .9, and the *efficiencies* by 1.1.

Example. How many square feet of radiation will be required to raise 600,000 cubic feet of air per hour from zero to 80 degrees, with a velocity through the heater of 800 feet per minute and a steam pressure of 5 pounds? What must be the total area of the heater front, and how many rows of pipes must it have?

Referring back to the formula for heat required for ventilation, we have

$$\frac{600{,}000 \times 80}{55} = 872{,}727 \text{ B. T. U. required.}$$

Referring to Table XXX, we find that for the above conditions a heater 10 pipes deep is required, and that an efficiency of 1,500 B. T. U. will be obtained. Then $\frac{872{,}727}{1{,}500} = 582$ square feet of surface required, which may be taken as 600 in round numbers. $\frac{600{,}000}{60} = 10{,}000$ cubic feet of air per minute; and $\frac{10{,}000}{800} = 12.5$ square feet of free area required through the heater. If we assume .4 of the total heater front to be free for the passage of air, then $\frac{12.5}{.4} = 31$ square feet, the total area required.

For convenience in estimating the approximate dimensions of a heater, Table XXXI is given. The standard heaters made by different manufacturers vary somewhat, but the dimensions given in the table represent average practice. Column 3 gives the square feet of heating surface in a single row of pipes of the dimensions given in columns 1 and 2; and column 4 gives the free area between the pipes.

TABLE XXXI

Dimensions of Heaters

Width of Section	Height of Pipes	Square Feet of Surface	Free Area through Heater in Sq. Ft.
3 feet	3 feet 6 inches	20	4.2
3 "	4 " 0 "	22	4.8
3 "	4 " 6 "	25	5.4
3 "	5 " 0 "	28	6.0
4 "	4 " 6 "	34	7.2
4 "	5 " 0 "	38	8.0
4 "	5 " 6 "	42	8.8
4 "	6 " 0 "	45	9.6
5 "	5 " 6 "	52	11.0
5 "	6 " 0 "	57	12.0
5 "	6 " 6 "	62	13.0
5 "	7 " 0 "	67	14.0
6 "	6 " 6 "	75	15.6
6 "	7 " 0 "	81	16.8
6 "	7 " 6 "	87	18.0
6 "	8 " 0 "	92	19.2
7 "	7 " 6 "	98	21.0
7 "	8 " 0 "	108	22.4
7 "	8 " 6 "	109	23.8
7 "	9 " 0 "	116	25.2

In calculating the total height of the heater, add 1 foot for the base.

These sections are made up of 1-inch pipe, except the last or 7-foot sections, which are made of 1¼-inch pipe.

Using this table in connection with the example just given, we should look in the last column for a section having a free area of 12.5 square feet; here we find that a 5 feet by 6 feet 6 inches section has a free opening of 13 square feet and a radiating surface of 62 square feet. The conditions call for 10 rows of pipes and 10 × 62 = 620 square feet of radiating surface, which is slightly more than called for, but which would be near enough for all practical purposes.

EXAMPLE FOR PRACTICE

Compute the dimensions of a heater to warm 20,000 cubic feet of air per minute from 10 below zero to 70 degrees above, with 5 pounds steam pressure.

Ans. 1,164 sq. ft. of rad. surface 10 pipes deep.
25 sq. ft. free area through heater.

Use twenty 5 ft. by 6 ft. sections, side by side, which gives 24 square feet area and 1,140 square feet of surface.

The general method of computing the size of heater for any given building is the same as in the case of indirect heating. First obtain the B. T. U. required for ventilation, and to that add the heat loss through walls, etc.; and divide the result by the efficiency of the heater under the given conditions.

Example. An audience hall is to be provided with 400,000 cubic feet of air per hour. The heat loss through walls, etc., is 250,000 B.T.U. per hour in zero weather. What will be the size of heater, and how many rows of pipe deep must it be, with 20 pounds steam pressure?

$$\frac{400{,}000 \times 70}{55} = 509{,}090 \text{ B. T. U. for ventilation.}$$

Therefore 250,000 + 509,090 = 759,090 B. T. U., total to be supplied.

We must next find to what temperature the entering air must be raised in order to bring in the required amount of heat, so that the number of rows of pipe in the heater may be obtained and its corresponding efficiency determined. We have entering the room for purposes of ventilation, 400,000 cubic feet of air every hour, at a temperature of 70 degrees; and the problem now becomes: To what temperature must this air be raised to carry in 250,000 B. T. U. additional for warming?

We have learned that 1 B. T. U. will raise 55 cubic feet of air 1 degree. Then 250,000 B. T. U. will raise 250,000 × 55 cubic feet of air 1 degree.

$$\frac{250{,}000 \times 55}{400{,}000} = 34 +$$

The air in this case must be raised to 70 + 34 = 104 degrees, to provide for both ventilation and warming. Referring to Table XXX, we find that a heater 12 pipes deep will be required, and that the corresponding efficiency of the heater will be 1,650 B. T. U. Then $\frac{759,090}{1,650}$ = 460 square feet of surface required.

Efficiency of Cast-Iron Heaters. Heaters made up of indirect pin radiators of the usual depth, have an efficiency of at least 1,500 B. T. U., with steam at 10 pounds pressure, and are easily capable of warming air from zero to 80 degrees or over when computed on this basis. The free space between the sections bears such a relation to the heating surface that ample area is provided for the flow of air through the heater, without producing an excessive velocity.

The heater shown in Fig. 139 may be counted on for an efficiency at least equal to that of a pipe heater; and in computing the depth, one row of sections may be taken as representing 4 rows of pipe.

Pipe Connections. In the heater shown in Fig. 135, all the sections take their supply from a common header, the supply pipe connecting with the top, and the return being taken from the lower division at the end, as shown.

In Fig. 137 the base is divided into two parts, one for live steam, and the other for exhaust. The supply pipes connect with the upper compartments, and the drips are taken off as shown. Separate traps should be provided for the two pressures.

The connections in Fig. 136 are similar to those just described, except that the supply and return headers, or bases, are drained through separate pipes and traps, there being a slight difference in pressure between the two, which is likely to interfere with the proper drainage if brought into the same one. This heater is arranged to take exhaust steam, but has a connection for feeding in live steam through a reducing valve if desired, the whole heater being under one pressure.

In heating and ventilating work where a close regulation of temperature is required, it is usual to divide the heater into several sections, depending upon its size, and to provide each with a valve in the supply and return. In making the divisions, special care should be taken to arrange for as many combinations as possible. For example, a heater 10 pipes deep may be made up of three sections—one of

2 rows, and two of 4 rows each. By means of this division, 2, 4, 6, 8, or 10 rows of pipe can be used at one time, as the outside weather conditions may require.

When possible, the return from each section should be provided with a water-seal two or three feet in depth. In the case of overhead heaters, the returns may be sealed by the water-line of the boiler or by the use of a special water-line trap; but vertical pipe heaters resting on foundations near the floor are usually provided with siphon loops extending into a pit. If this arrangement is not convenient, a separate trap should be placed on the return from each section. The main return, in addition to its connection with the boiler or pump receiver, should have a connection with the sewer for blowing out when steam is first turned on. Sometimes each section is provided with a connection of this kind.

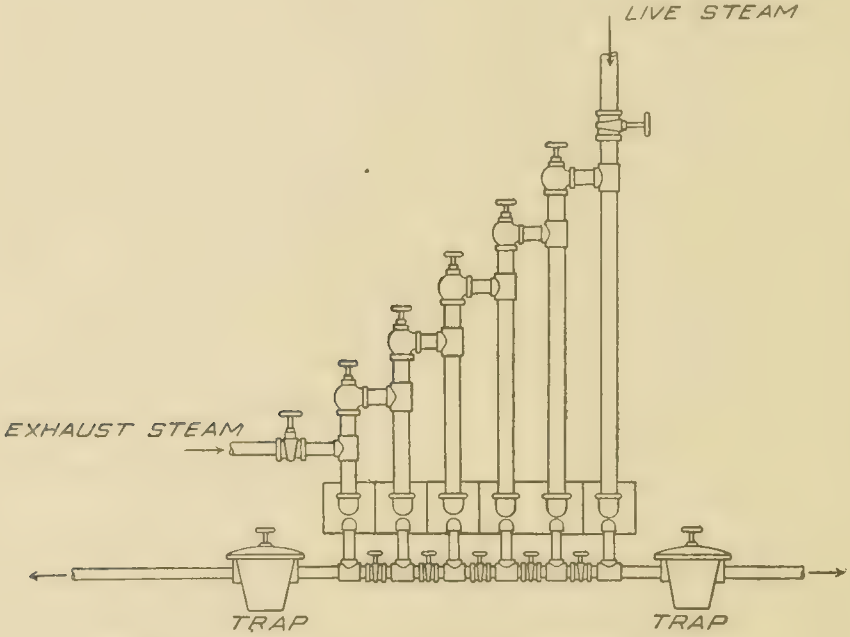


Fig. 140. Heater Made Up of Interchangeable Sections.

Large automatic air-valves should be connected with each section; and it is well to supplement these with a hand pet-cock, unless individual blow-off valves are provided as described above.

If the fan is driven by a steam engine, provision should be made for using the exhaust in the heater; and part of the sections should be so valved that they may be supplied with either exhaust or live steam.

Fig. 140 shows an arrangement in which all of the sections are interchangeable.

From 50 to 60 square feet of radiating surface should be provided in the exhaust portion of the heater for each engine horse-power, and should be divided into at least three sections, so that it can be proportioned to the requirements of different outside temperatures.

Pipe Sizes. The sizes of the mains and branches may be computed from the tables already given in Part II, taking into account the higher efficiency of the heater and the short runs of piping.

Table XXXII, based on experience, has been found to give satisfactory results when the apparatus is near the boilers. If the main supply pipe is of considerable length, its diameter should be checked by the method previously given.

TABLE XXXII

Pipe Sizes

Square Feet of Surface	Diameter of Steam Pipe	Diameter of Return
150	2 inches	1¼ inches
300	2½ "	1½ "
500	3 "	2 "
700	3½ "	2 "
1,000	4 "	2½ "
2,000	5 "	2½ "
3,000	6 "	3 "

Heaters of the patterns shown in Figs. 135, 136, and 137 are usually tapped at the factory for high or low pressure as desired, and these sizes may be followed in making the pipe connections.

The sizes marked on Fig. 136 may be used for all ordinary work where the pressure runs from 5 to 20 pounds; for pressures above that, the supply connections may be reduced one size.

FANS

There are two types of fans in common use, known as the *centrifugal fan* or *blower,* and the *disc fan* or *propeller.* The former consists of a number of straight or slightly curved blades extending radially from an axis, as shown in Fig. 141. When the fan is in motion, the air in contact with the blades is thrown outward by the action of centrifugal force, and delivered at the circumference or periphery of the wheel. A partial vacuum is thus produced at the center of the wheel, and air from the outside flows in to take the place of that which has been discharged.

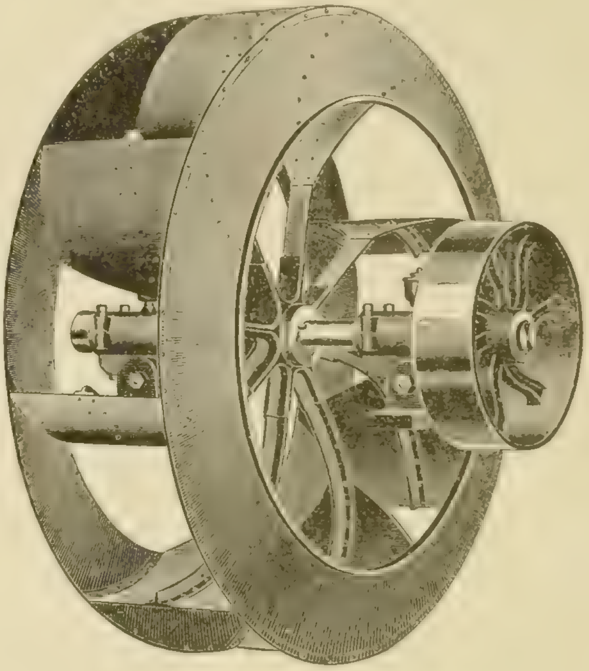


Fig. 141. Centrifugal Fan or Blower.

Fig. 142 illustrates the action of a centrifugal fan, the arrows showing the path of the air. This type of fan is usually enclosed in a steel-plate casing of such form as to provide for the free movement of the air as it escapes from the periphery of the wheel. An opening in the circumference of the casing serves as an outlet into the distributing ducts which carry the air to the various rooms to be ventilated.

A fan with casing, is shown in Fig. 143; and a combined heater and fan, with direct-connected engine, is shown in Fig. 144.

The discharge opening can be located in any position desired, either up, down, top horizontal, bottom horizontal, or at any angle.

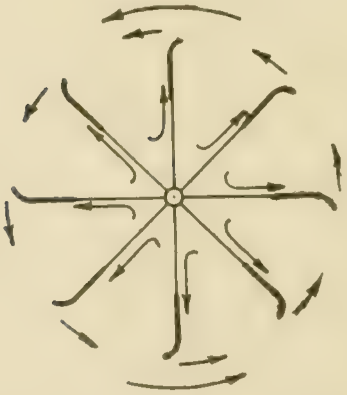


Fig. 142. Illustrating Action of Centrifugal Fan. The Arrows Show the Path of the Air.

Where the height of the fan room is limited, a form called the *three-quarter housing* may be used, in which the lower part of the casing is replaced by a brick or cemented pit extending below the floor-level as shown in Fig. 145.

Another form of centrifugal fan is shown in Fig. 146. This is known as the *cone fan,* and is commonly placed in an opening in a brick wall, and discharges air from its entire periphery into a room called a *plenum chamber,* with which the various distributing ducts connect.

This fan is often made double by placing two wheels back to back and surrounding them with a steel casing in a similar manner to the one shown in Fig. 143.

Cone fans are particularly adapted to church and schoolhouse work, as they are capable of moving large volumes of air at moderate speeds.

Fig. 147 shows a form of small direct-connected exhauster commonly used for ventilating toilet-rooms, chemical hoods, etc.

Centrifugal fans are used almost exclusively for supplying air for the ventilation of buildings, and for forced-blast heating. They are also used as exhausters for removing the air from buildings in cases where there is considerable resistance due to the small size or excessive length of the discharge ducts.

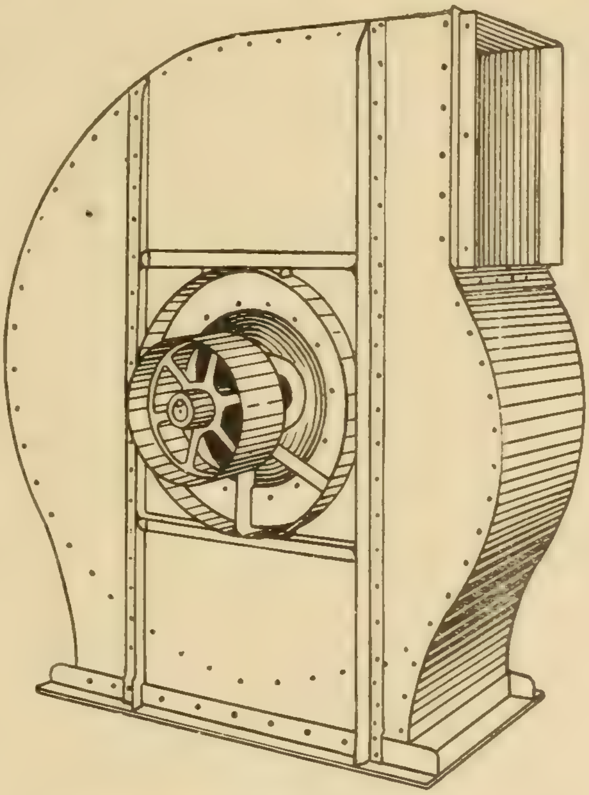


Fig. 143. Centrifugal Fan with Casing.

General Proportions. The general form of a fan wheel is shown in Fig. 141, which represents a single spider wheel with curved blades. Those over 4 feet in diameter usually have two spiders, while fans of large size are often provided with three or more. The number of floats or blades commonly varies from six to twelve, depending upon the diameter of the fan. They are made both curved and straight; the former, it is claimed, run more quietly, but, if curved too much, will not work so well against a high pressure as the latter form.

The relative proportions of a fan wheel vary somewhat in the case of different makes. The following are averages taken from fans of different sizes as made by several well-known manufacturers for general ventilating and similar work:

Width of fan at center = Diameter × .52
Width of fan at perimeter = Width at center × .8
Diameter of inlet = Diameter of wheel × .68

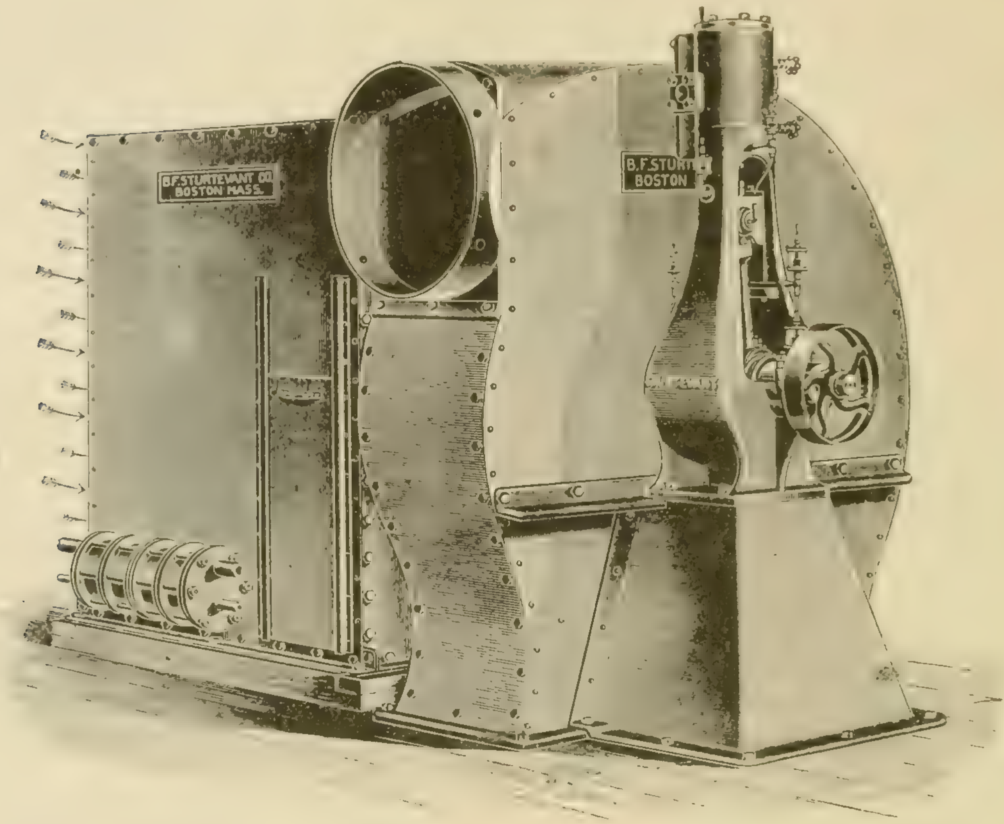


Fig. 144. Combined Heater and Centrifugal Fan with Direct-Connected Engine.

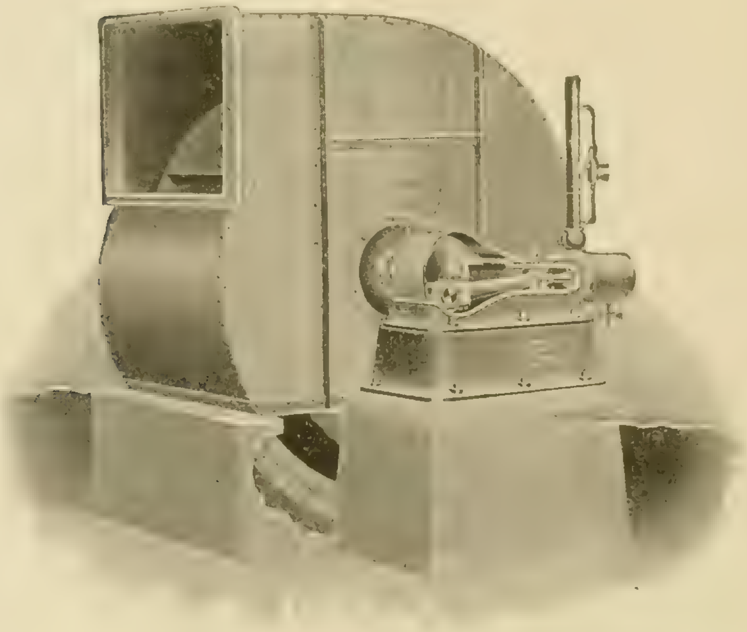


Fig. 145. Centrifugal Fan in "Three-Quarter Housing." Used where Headroom is Limited; Extra Space Provided by Pit under Floor-Level.

Fans are made both with double and with single inlets, the former being called *blowers* and the latter *exhausters*. The size of a fan is commonly expressed in inches, which means the approximate height of the casing of a full-housed fan. The diameter of the wheel is usually expressed in feet, and can be found in any given case by dividing the size in inches by 20. For example, a 120-inch fan has a wheel 120 ÷ 20 = 6 feet in diameter.

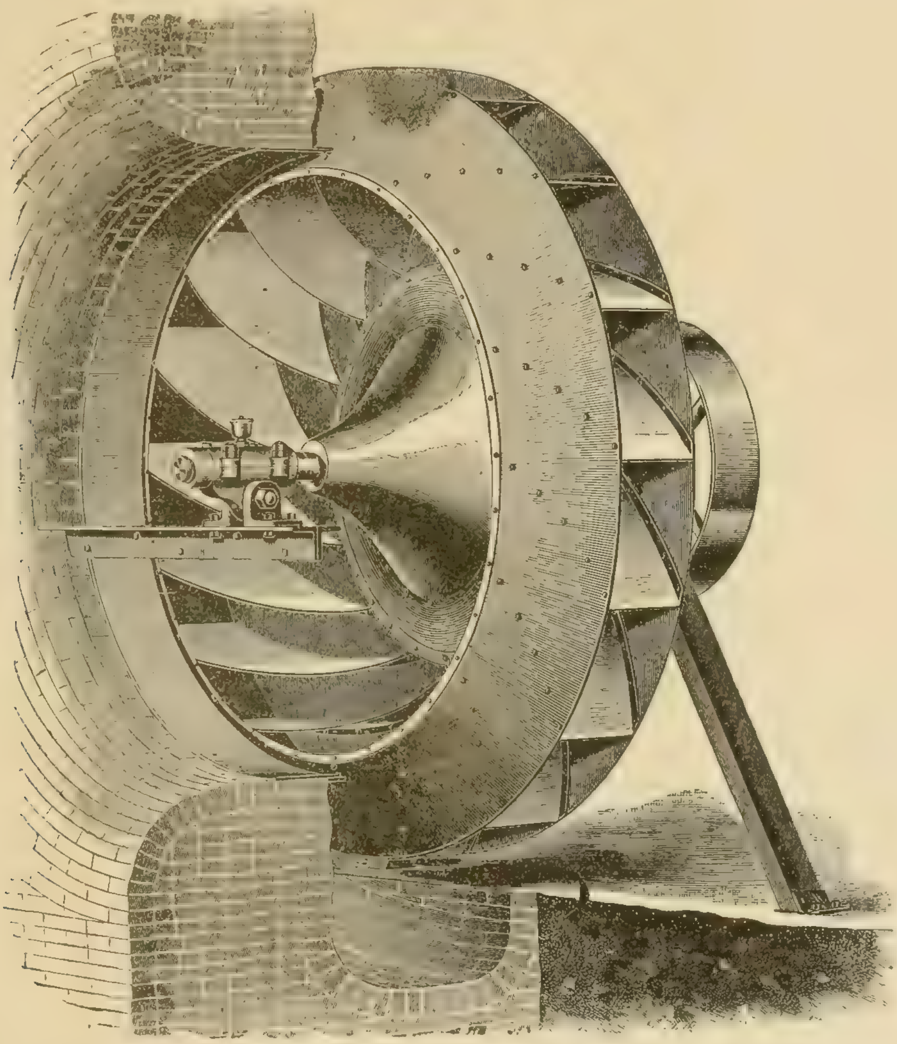


Fig. 146. "Cone" Fan. Discharges through Opening in Wall into a "Plenum Chamber" Connecting with Distributing Ducts.

Theory of Centrifugal Fans. The action of a fan is affected to such an extent by the various conditions under which it operates, that it is impossible to give fixed rules for determining the exact results to be expected in any particular instance. This being the case, it seems best to take up the matter briefly from a theoretical standpoint, and then show what corrections are necessary in the case of a given fan under actual working conditions.

There are various methods for determining the capacity of a fan at different speeds, and the power necessary to drive it; each manufacturer has his own formulæ for this purpose, based upon tests of his own particular fans. The methods given here apply in a general way to fans having proportions which represent the *average* of several standard makes; and the results obtained will be found to correspond well with those obtained in practice under ordinary conditions.

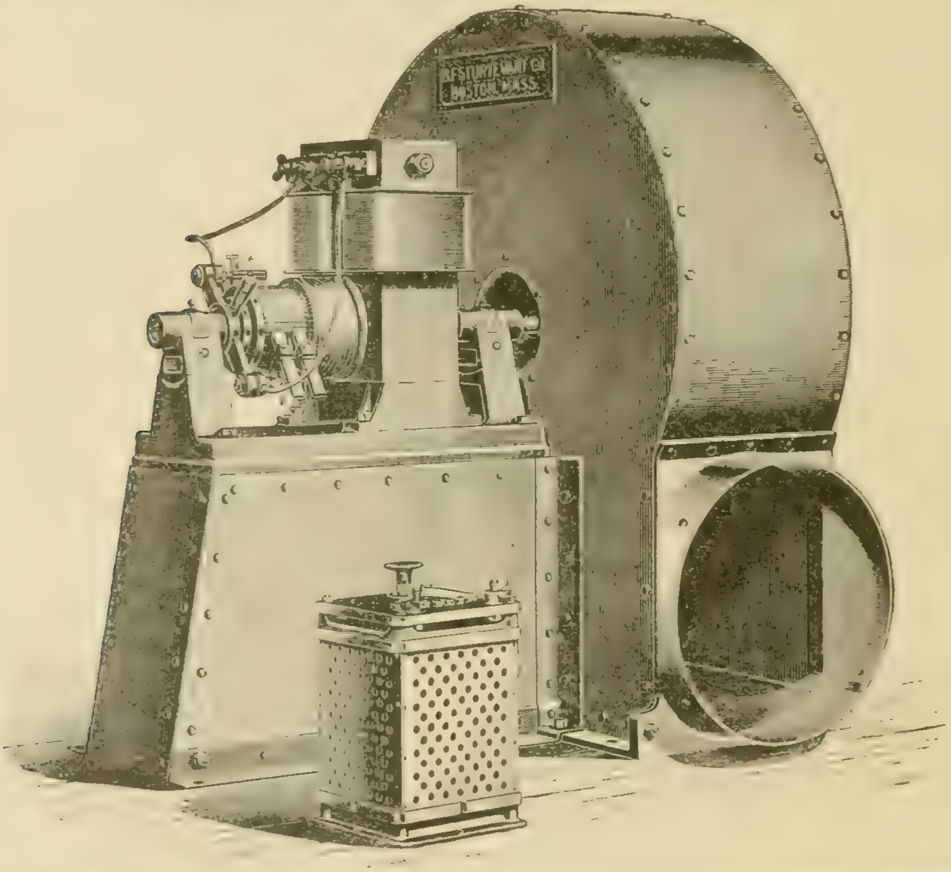


Fig. 147. Small, Direct-Connected Exhauster for Ventilating Toilet-Rooms, Chemical Hoods, etc.

As already stated, the rotation of a fan of this type sets in motion the air between the blades, which, by the action of centrifugal force, is delivered at the periphery of the wheel into the casing surrounding it. As the velocity of flow through the discharge outlet depends upon the pressure or head within the casing, and this in turn upon the velocity of the blades, it becomes necessary to examine briefly into the relations existing between these quantities.

Pressure. The pressure referred to in connection with a fan, is that in the discharge outlet, and represents the force which drives the air through the ducts and flues. The greater the pressure with a given resistance in the pipes, the greater will be the volume of air delivered; and the greater the resistance, the greater the pressure required to deliver a given quantity.

The pressure within a fan casing is caused by the air being thrown from the tips of the blades, and varies with the velocity of rotation; that is, the higher the speed of the fan, the greater will be the pressure produced. Where the dimensions of a fan and casing are properly proportioned, the velocity of air-flow through the outlet will be the same as that of the tips of the blades, and the pressure within the casing will be that corresponding to this velocity.

Table XXXIII gives the necessary speed for fans of different diameters to produce different pressures, and also the velocity of air-flow due to these pressures.

TABLE XXXIII

Fan Speeds, Pressures, and Velocities of Air-Flow

Pressure, in Ounces per Sq. Inch	Diameter of Fan Wheel, in Feet								Velocity of Flow in Feet per Minute
	3	4	5	6	7	8	9	10	
	Revolutions per Minute								
$\frac{1}{4}$	274	206	164	137	117	103	92	82	2,585
$\frac{3}{8}$	336	252	202	168	144	126	112	101	3,165
$\frac{1}{2}$	338	291	232	194	166	146	129	116	3,653
$\frac{5}{8}$	433	325	260	217	186	163	144	130	4,084

The application of this table will be made plain by a brief discussion of *blast area.*

Blast Area. When the outlet from a fan casing is small, the air will pass out with a velocity equal to that of the tips of the blades; and the pressure within the casing will be that corresponding to the tip velocity. That is, a 3-foot fan wheel revolving at a speed of 274 revolutions per minute will produce a pressure within the fan casing of $\frac{1}{4}$ ounce per square inch, and will cause a velocity of flow through the discharge outlet of 2,585 feet per minute (see Table XXXIII).

Now, if the opening be slowly increased, while the speed of the fan remains constant, the air will continue to flow with the same velocity until a certain area of outlet is reached. If the outlet be still further increased, the pressure in the casing will begin to drop, and the velocity of outflow become less than the tip velocity. The effective area of outlet at the point when this change begins to take place, is called the *blast area* or *capacity area* of the fan. This varies somewhat with different types and makes of fans; but for the common form of blower, it is approximately $\frac{1}{3}$ of the projected area of the fan opening at the periphery—that is, $\frac{Dw}{3}$, in which D is the diameter of the fan wheel, and w its width at the periphery. It has already been stated under "General Proportions" that $W = .52\,D$, and $w = .8\,W$; so that we may write $A = \frac{D \times .8\,W}{3} = \frac{D \times .8 \times .52\,D}{3} = .14\,D^2$, in which A = the blast area, and D the diameter of the fan.

As a matter of fact, the outlet of a fan casing is always made larger than the blast area; and the result is that the pressure drops below that due to the tip velocity, and the velocity of flow through the outlet becomes less than that given in the last column of Table XXXIII for any given speed of fan.

Effective Area of Outlet. The size of discharge outlet varies somewhat for different makes; but for a large number of fans examined it was found to average about 2.22 times the blast area as computed by the above method. When air or a liquid flows through an orifice, the stream is more or less contracted, depending upon the form of the orifice.

In the case of a fan outlet, the *effective area* may be taken as about .8 of the actual area. This makes the effective area of a fan outlet equal to $.8 \times 2.22 = 1.78$ times the blast area.

Table XXXIV gives the effective areas of fans of different diameter as computed by the above method. That is, Effective area = $.14D^2 \times 1.78 = .25D^2$.

Speed. We have seen that when the discharge outlet is made larger than the blast area, the pressure within the fan casing drops below that due to the tip velocity; so that, in order to bring the pressure up to its original point, the speed of the fan must be increased above that given in Table XXXIII.

TABLE XXXIV

Effective Areas of Fans

Diameter of Fan, in Feet	Effective Area of Outlet, in Square Feet
3	2.3
4	4.0
5	6.3
6	9.1
7	12.3
8	16.0
9	20.4
10	25.2

Tests upon a fan of practically the same proportions as those previously given, show that, when the effective outlet area is made 1.78 the blast area, the speed must be increased 1.2 times in order to keep the pressure at the same point as when the outlet is equal to or less than the blast area.

Capacity. The capacity of a fan is the volume of air discharged in a given time, and is usually expressed in cubic feet per minute. It is equal to the effective area of discharge *multiplied by* the velocity of flow through it.

Example. At what speed must a 6-foot fan be run to maintain a pressure of ½ ounce, and what volume of air will be delivered per minute?

From Table XXXIII we find that a 6-foot fan must run at a speed of 194 revolutions per minute to maintain the given pressure when the outlet is equal to the blast area, or 194 × 1.2 = 233 revolutions per minute under actual conditions. The velocity of flow through the outlet at ½ ounce pressure, is 3,653 feet per minute (Table XXXIII); and the effective area of outlet of a 6-foot fan is 9.1 square feet (Table XXXIV). Therefore the volume of air delivered per minute is equal to 9.1 × 3,653 = 33,242 cubic feet.

Example. It is desired to move 52,000 cubic feet of air per minute at a pressure of ¼ ounce. What size and speed of fan will be required? Looking in Table XXXIII, we find that the velocity through the fan outlet for ¼-ounce pressure is 2,585, which calls for an outlet area of 52,000 ÷ 2,585 = 20.1 square feet. Looking in Table XXXIV, we find this corresponds very nearly to a 9-foot fan, which is the size called for. Referring again to Table XXXIII, the speed necessary to maintain the required pressure under the given conditions is found to be 92 × 1.2 = 110 revolutions per minute.

Effect of Resistance. Thus far it has been assumed that the fan was discharging into the open air against atmospheric pressure. The effect of adding a resistance by connecting it with a series of ventilating ducts, is the same as partially closing the discharge outlet. Carefully conducted tests upon this type of fan have shown that the reduction of air-flow is very nearly in proportion to the reduction of the discharge area. That is, if the outlet of the fan is closed to one-half its original area, the quantity of air discharged will be practically one-half that delivered by the fan with a free opening. The effect of attaching a fan to the ventilating flues of a building like a schoolhouse, church, or hall, where the ducts have easy bends and where the velocity of air-flow through them is not over 1,000 to 1,200 feet per minute, is about the same as reducing the outlet 20 per cent. For factories with deep heaters and smaller ducts, where the velocity runs up to 1,500 or 1,800 feet per minute, the effect is equivalent to closing the outlet at least 30 per cent, and even more in very large buildings.

For schoolhouses and similar work a fan should not be run much above the speed necessary to maintain a pressure of $\frac{3}{8}$ ounce at the outlet. Higher speeds are accompanied with greater expenditure of power, and are likely to produce a roaring noise or to cause vibration. A much lower speed does not provide sufficient pressure to give proper control of the air-distribution during strong winds. For factories, a higher pressure of $\frac{5}{8}$ to $\frac{3}{4}$ ounce is more generally employed.

Actually the pressure is increased slightly by restricting the outlet at constant speed; but this is seldom taken into account in ventilating work, as volume, speed, and power are the quantities sought.

Example. A school building requires 32,000 cubic feet of air per minute. What size and speed of fan will be required?

If the resistance of the ducts and flues is equivalent to cutting down the discharge outlet 20 per cent, we must make the computations for a fan which will discharge 32,000 ÷ .8 = 40,000 cubic feet in free air.

Looking in Table XXXIII, we find the velocity for $\frac{3}{8}$-ounce pressure to be 3,165 feet per minute; therefore the size of fan outlet must be 40,000 ÷ 3,165 = 12.6 square feet, which, from Table XXXIV, we find corresponds very nearly to a 7-foot fan.

Referring again to Table XXXIII, the required speed is found to be 144 × 1.2 = 173 revolutions per minute.

Example. A factory requires 21,000 cubic feet of air per minute for warming and ventilating. What size and speed of fan will be required?

21,000 ÷ .7 = 30,000, the volume to provide for with a fan discharging into free air. Assuming a pressure of $\frac{5}{8}$ ounce, the velocity will be 4,084 feet per minute, from which the area of outlet is found to be 30,000 ÷ 4,084 = 7.3 square feet. This, we find, does not correspond to any of the sizes given in Table XXXIV. As standard fans are not usually made in half-sizes above 5 feet, we shall use a 5-foot fan and run it at a higher speed.

A 5-foot fan has an outlet area of 6.3 square feet, and at $\frac{5}{8}$-ounce pressure it would deliver 6.3 × 4,084 = 25,729 cubic feet of air per minute, at a speed of 260 × 1.2 = 312 revolutions per minute. The volume of air delivered by a fan varies approximately as the speed; so, in order to bring the volume up to the required 30,000, the speed must be increased by the ratio 30,000 ÷ 25,729 = 1.16, making the final speed 312 × 1.16 362 revolutions per minute. In the same way, a 6-foot fan could have been used and run at a proportionally lower speed.

Power Required. The work done by a fan in moving air is represented by the pressure exerted, *multiplied by* the distance through which it acts.

Table XXXV gives the horse-power required for moving the air which will flow through each square foot of the effective outlet area, under different pressures.

This table gives only the power necessary for *moving* the air, and does not take into consideration the friction of the air in passing through the fan, nor that of the fan itself.

The efficiency of a fan varies with the speed, the size of outlet, and the pressure against which the fan is working. Under favorable conditions, with properly proportioned fans, we may count on an efficiency of about .35.

Example. What horse-power will be required to drive an 8-foot fan at such a speed as to maintain a pressure of $\frac{1}{2}$ ounce?

An 8-foot fan has an outlet area of 16 square feet (Table XXXIV); and from Table XXXV we find that .5 horse-power is required to move the air which will flow through each square foot of outlet under

TABLE XXXV

Power Required for Moving Air under Different Pressures

Pressure in Ounces per Square Inch	Horse-Power for Moving Air which will Flow through Each Square Foot of Effective Outlet Area
$\frac{1}{4}$	.18
$\frac{3}{8}$	.33
$\frac{1}{2}$	.50
$\frac{5}{8}$	.70

$\frac{1}{2}$-ounce pressure. Therefore the power required to move the air alone is $16 \times .5 = 8$, and the total horse-power is $8 \div .35 = 23$.

Effect of Resistance. In the above case, it is assumed that the fan is discharging into free air. If a resistance is added, the effect is the same as partially closing the outlet, and the volume of air moved and the horse-power required are both reduced in very nearly the same proportion. This reduction, as already stated, may be taken as 20 per cent for schoolhouse and similar work, and 30 per cent for factories.

For example, if the fan just considered was to be used for ventilating a schoolhouse, delivering air under a pressure of $\frac{1}{2}$ ounce, the necessary horse-power would be only $23 \times .8 = 18.4$. If used for a factory, delivering air under a pressure of $\frac{5}{8}$ ounce, the required horse-power would be $\frac{16 \times .7}{.35} \times .7 = 22.3$.

General Rules. The methods above described may be briefly expressed as follows:

Capacity—$Q = A \times v \times F$, in which
Q = Cubic feet of air per minute;
A = Effective area of fan outlet (Table XXXIV);
v = Velocity of flow through outlet;

$$\begin{cases} 3{,}165\ (\tfrac{3}{8}\text{-ounce pressure) for schoolhouses, etc.;} \\ 4{,}084\ (\tfrac{5}{8}\text{-ounce pressure) for factories;} \end{cases}$$

$$F = \begin{cases} .8 \text{ for schoolhouses, etc.;} \\ .7 \text{ for factories.} \end{cases}$$

Speed—Take the speed from Table XXXIII, corresponding to the given pressure and size of fan, and multiply by 1.2.

Horse-Power—$\text{H.P.} = \frac{A \times p \times F}{.35}$, in which
H.P. = Horse-power;
A = Effective area of fan outlet;
p = Horse-power to move air which will flow through 1 square foot of fan outlet under given pressure (Table XXXV);

$$= \begin{cases} \text{.33 for schoolhouses, etc.;} \\ \text{.7 for factories.} \end{cases}$$

$$F = \begin{cases} \text{.8 for schoolhouses, etc.;} \\ \text{.7 for factories.} \end{cases}$$

EXAMPLES

1. A schoolhouse requires an air-supply of 30,000 cubic feet per minute. What will be the required size of fan, its speed, and the H. P. of engine to drive it?

$$\text{Ans.} \begin{cases} \text{7 ft. in diameter.} \\ \text{173 r. p. m.} \\ \text{9 H. P.} \end{cases}$$

2. What will be the size and speed of fan, and horse-power of engine, to heat and ventilate a factory requiring 1,080,000 cubic feet of air per hour?

$$\text{Ans.} \begin{cases} \text{6 ft. in diameter.} \\ \text{260 r. p. m.} \\ \text{8.8 H. P.} \end{cases}$$

General Relations. The following general relations between the volume, pressure, and power will often be found useful in deciding upon the size of a fan:

(1) The volume of air delivered varies *directly* as the speed of the fan; that is, doubling the number of revolutions doubles the volume of air delivered.

(2) The pressure varies as the *square* of the speed. For example, if the speed is doubled, the pressure is increased 2 × 2 = 4 times; etc.

(3) The power required to run the fan varies as the *cube* of the speed. Thus, if the speed is doubled, the power required is increased 2 × 2 × 2 = 8 times; etc.

The value of a knowledge of these relations may be illustrated by the following example:

Suppose for any reason it were desired to double the volume of air delivered by a certain fan. At first thought we might decide to use the same fan and run it twice as fast; but when we come to consider the power required, we should find that this would have to be increased 8 times, and it would probably be much cheaper in the long run to put in a larger fan and run it at lower speed.

Disc or Propeller Fans. When air is to be moved against a very slight resistance, as in the case of exhaust ventilation, the disc or propeller type of wheel may be used. This is shown in different forms in Figs. 149 and 150. This type of fan is light in construction, requires but little power at low speeds, and is easily erected. It may be conveniently placed in the attic or upper story of a building, where it may be driven either by a direct- or belt-connected electric motor. Fig. 148 shows a fan equipped with a direct-connected motor, and Fig. 151 the general arrangement when a belted motor is used. These fans are largely used for the ventilation of toilet and smoking rooms, restaurants, etc., and are usually mounted in a wall opening, as shown in Fig. 151. A damper should always be provided for shutting off the opening when the fan is not in use. The fans shown in Figs. 149 and 150 are provided with pulleys for belt connection.

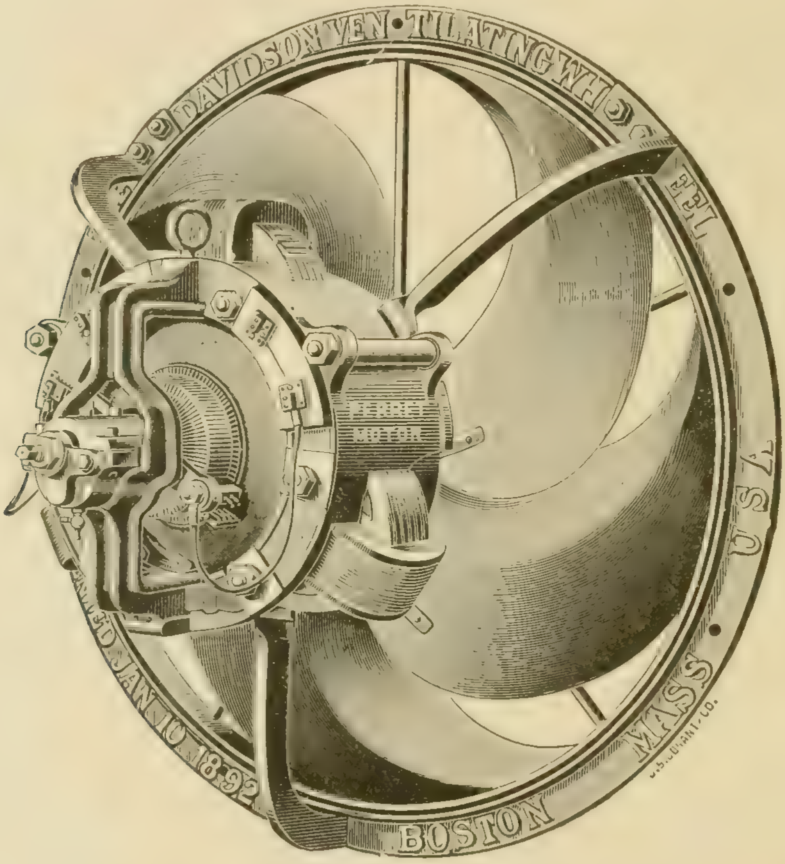


Fig. 148. Propeller Fan Direct-Connected to Motor.

Fans of this kind are often connected with the main vent flues of large buildings, such as schools, halls, churches, theaters, etc., and are especially adapted for use in connection with gravity heating systems. They are usually run by electric motors, and as a rule are placed in positions where an engine could not be connected, and also in buildings where steam pressure is not available.

Capacity of Disc Fans. The capacity of a disc fan varies greatly with the type and the conditions under which it operates. The rated capacities usually given in catalogues are for fans revolving in free air—that is, mounted in an opening without being connected with ducts or subjected to other frictional resistance.

As the capacity and necessary power are so dependent upon the resistance to be overcome, it is difficult to give definite rules for determining them. The following data, based upon actual tests,

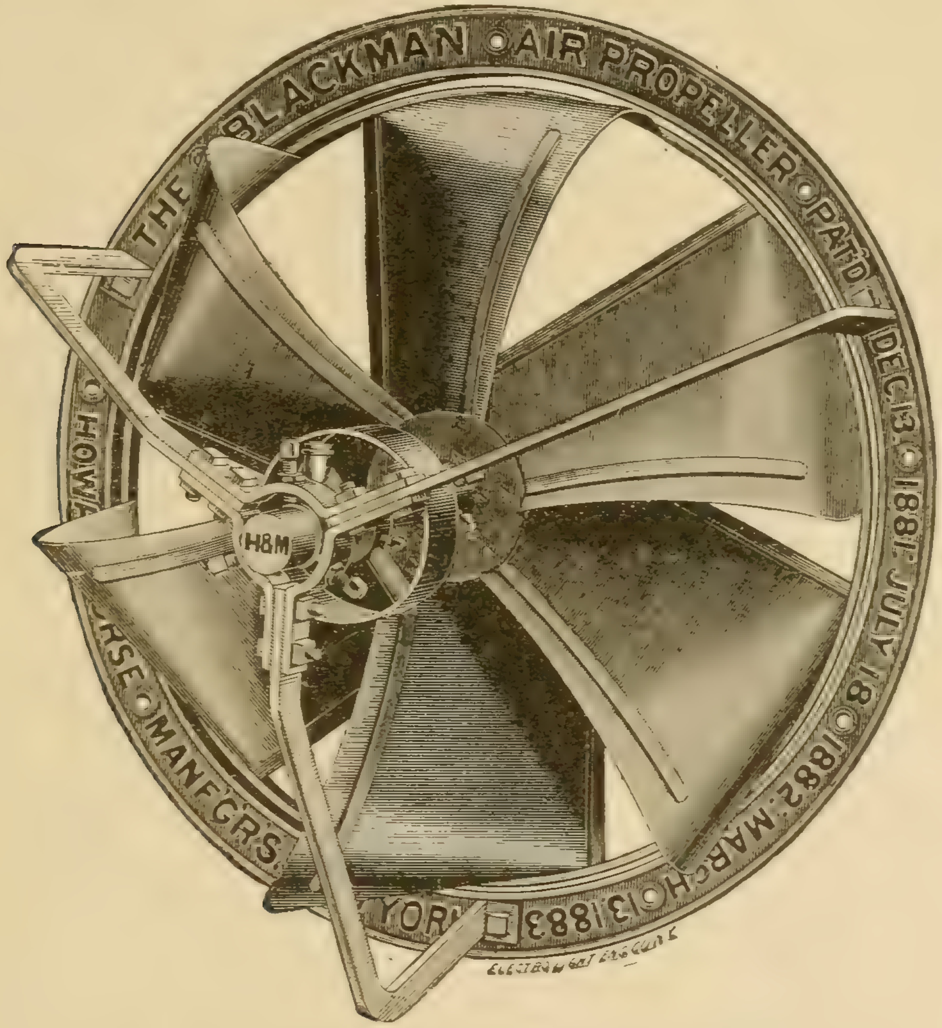


Fig. 149. Another Form of Propeller Fan, with Special Type of Blade.

apply to fans working against a resistance such as would be produced by connecting with a system of ducts of medium length through which the air was drawn at a velocity not greater than 600 or 800 feet per minute. Under these conditions, a good type of fan will propel the air in a direction parallel to the shaft a distance equal to about .7 of its diameter at each revolution; and from this we have the equation:

$$Q = .7\ D \times R \times A,$$

in which

Q = Cubic feet of air discharged per minute;
D = Diameter of fan, in feet;
R = Revolutions per minute;
A = Area of fan, in square feet.

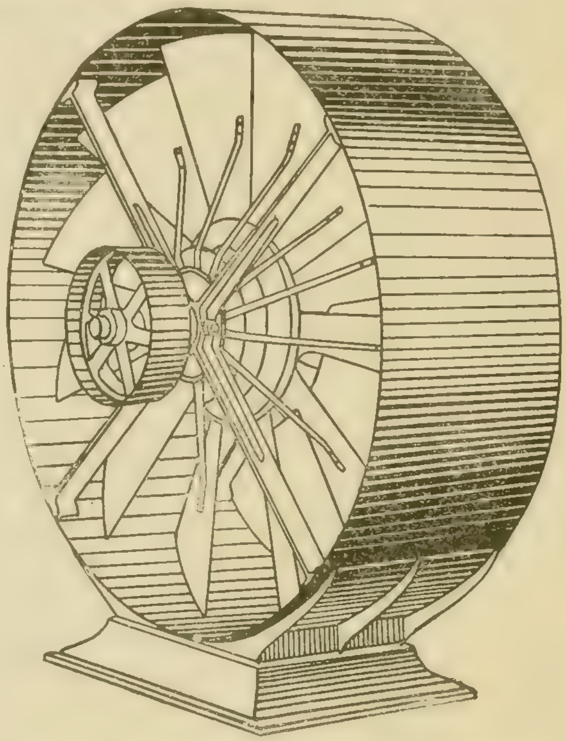


Fig. 150. Propeller Fan with Wheel on Shaft for Belt Connection.

In order to obtain the best results, the linear velocity of air-flow through the fan should range from 800 to 1,200 feet per minute.

Table XXXVI gives the revolutions per minute for fans of different diameter to produce a linear velocity of 1,000 feet, the volume delivered at this speed, and the horse-power required.

The horse-power is computed by allowing .14 H. P. for each 1,000 cubic feet of air moved, when the velocity through the fan is 800 feet per minute; .16 H. P. for 1,000 feet velocity; and .18 H. P. for 1,200 feet velocity. These factors are empirical, and based on tests.

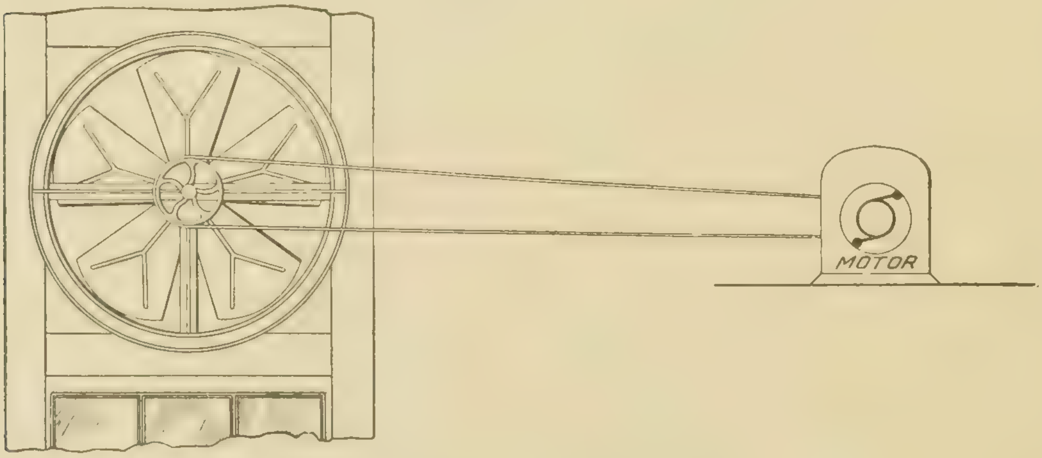


Fig. 151. Fan Belt-Connected to Motor.

Example. Assuming a velocity of 800 feet per minute through a 4-foot fan, what volume will be delivered per minute, and what speed and horse-power will be required?

TABLE XXXVI

Disc Fans, their Capacity, Speed, etc.

Dia. of Fan, in Inches	Rev. per Min.	Cubic Feet of Air Moved	Horse-Power Required
18	952	1,700	.27
24	716	3,100	.50
30	572	4,900	.78
36	476	7,100	1.2
42	408	9,400	1.5
48	343	12,000	1.9
54	317	15,800	2.5
60	286	19,400	3.1
72	238	28,300	4.5

The area of a 4-foot fan is 12.5 square feet; and at 800 velocity the volume would be $12.5 \times 800 = 10{,}000$ cubic feet. Next solve for the speed by the equation $Q = .7D \times R \times A$, which, when transposed, takes the form

$$R = \frac{Q}{.7\,D \times A}.$$

Substituting the known quantities, we have:

$$R = \frac{10{,}000}{.7 \times 4 \times 12.5} = 286.$$

The horse-power is $10 \times .14 = 1.4$.

Fan Engines. A simple, quiet-running engine is desirable for use in connection with a fan or blower. The engine may be either horizontal or vertical; and for schoolhouse and similar work, should be provided with a large cylinder, so that the required power may be developed without carrying a boiler pressure much above 30 pounds. In some cases, cylinders of such size are used that a boiler pressure of 12 or 15 pounds is sufficient. The quantity of steam which an engine consumes is of minor importance, as the exhaust can be turned into the coils and used for heating purposes. If space allows, the engine should always be belted to the fan. Where it is direct-connected, as in Fig. 144, there is likely to be trouble from noise, as any slight looseness or pounding in the engine will be communicated to the air-ducts, and the sound will be carried to the rooms above. Figs. 152 and 153 show common forms of fan engines. The latter is especially adapted to this purpose, as all bearings are enclosed and protected from dust and grit. A horizontal engine for fan use is shown in Fig. 154.

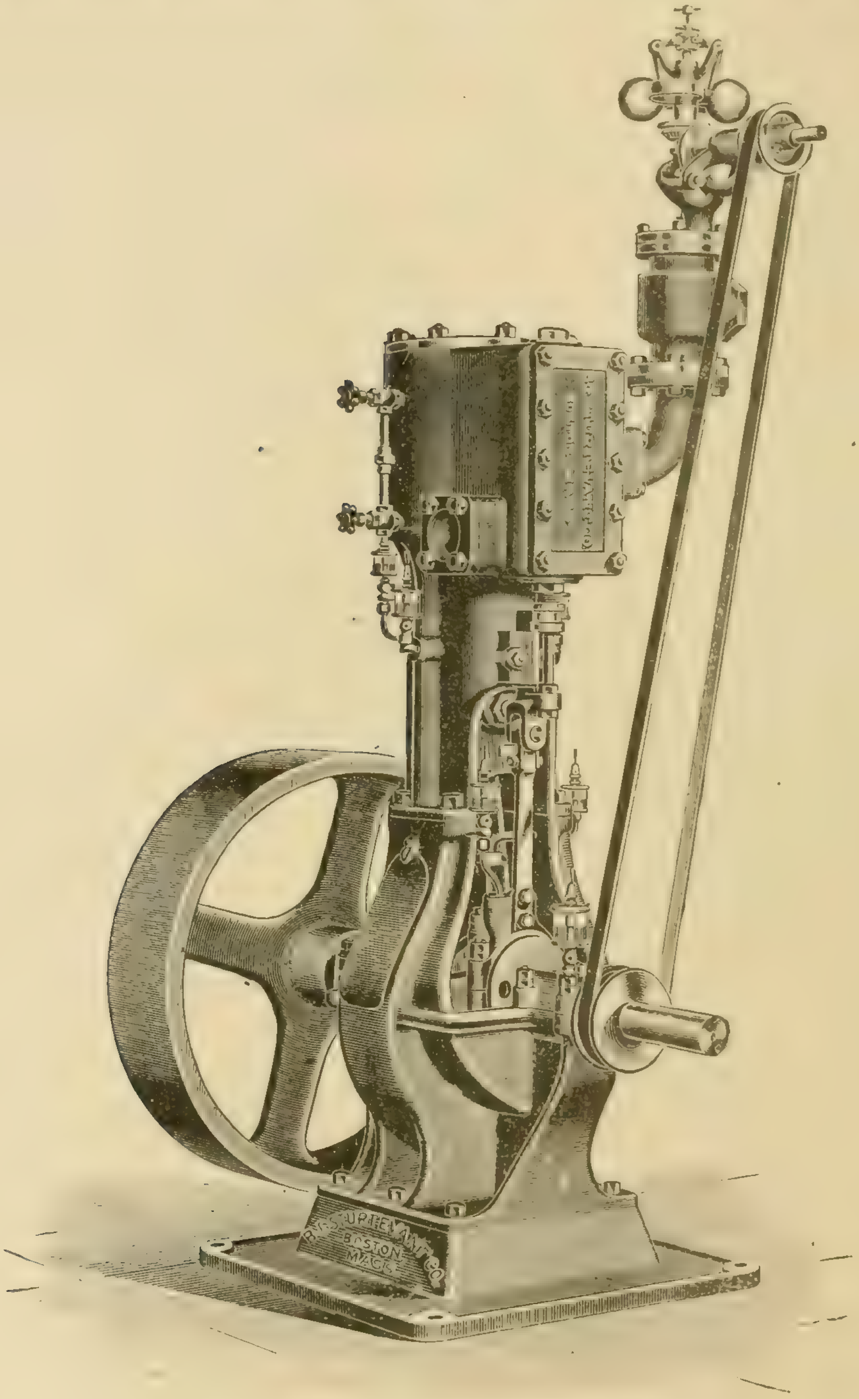
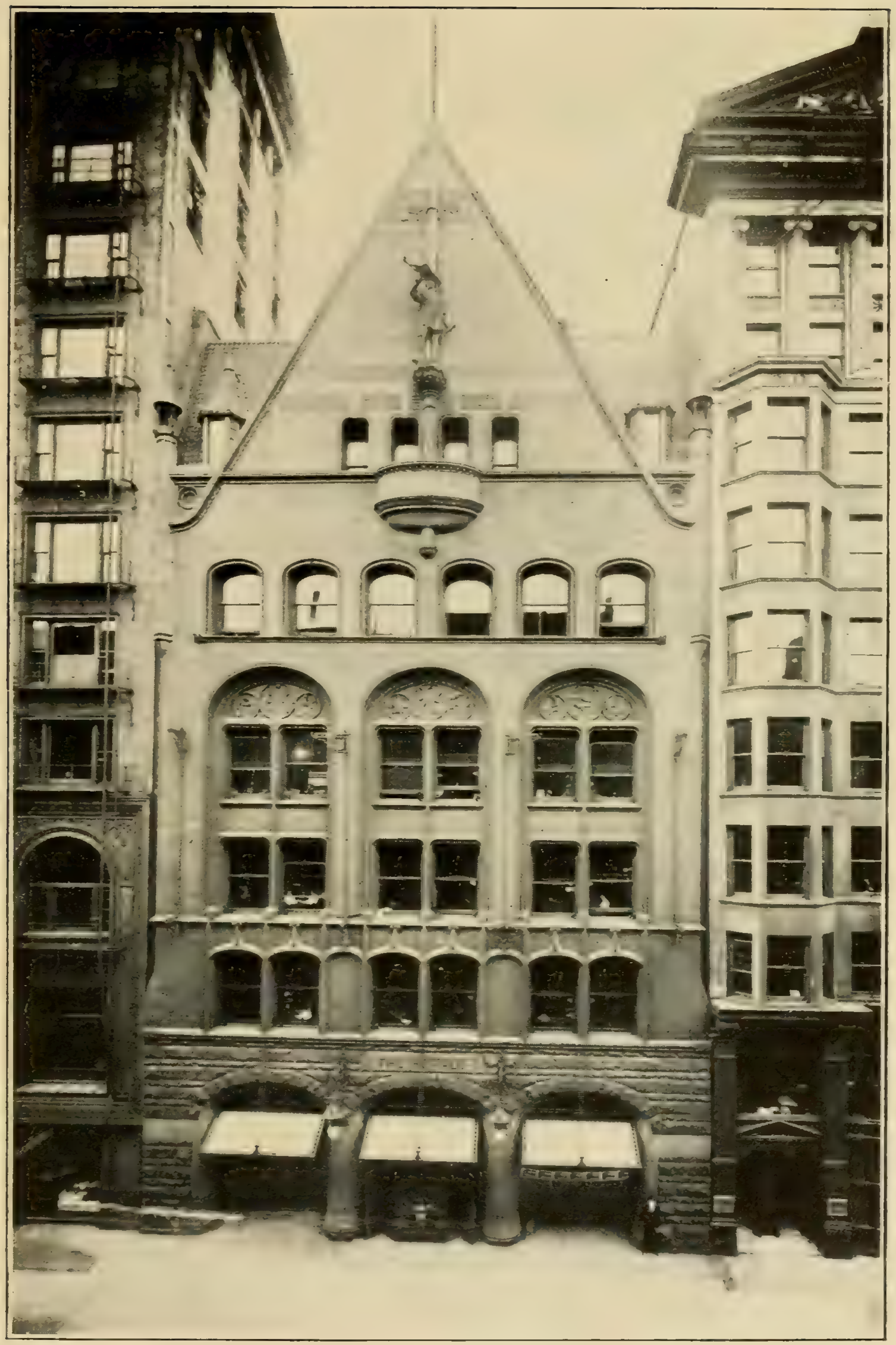


Fig. 152 A Common Form of Fan Engine.

In case an engine is belted, the distance between the shafts of the fan and engine should not in general be much less than 10 feet



RECORD-HERALD BUILDING, CHICAGO, ILL.

Burnham & Root, Architects.

Exterior of Granite and Terra-Cotta. Built in 1890.

for fans up to 7 or 8 feet in diameter, and 12 feet for those of larger size. When possible, the tight or driving side of the belt should be at the bottom, so that the loose side, coming on top, will tend to wrap around the pulleys and so increase the arc of contact.

Motors. Electric motors are especially adapted for use in connection with fans. This method of driving is more expensive than by the use of an engine, especially if electricity must be purchased from outside parties; but if the building contains its own power plant, so that the exhaust steam can be utilized for heating, the convenience and simplicity of motor-driven fans often more than offset the additional cost of operation.

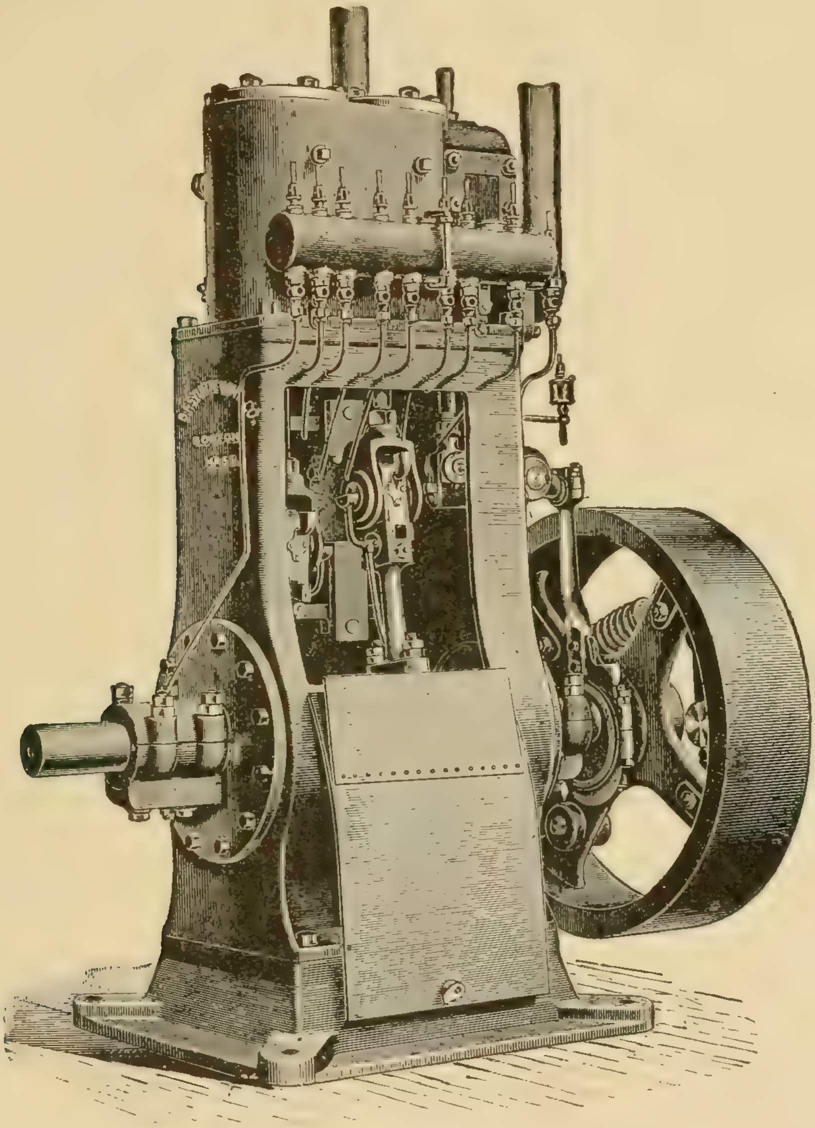


Fig. 153. Another Form of Fan Engine, with Bearings Enclosed to Protect Them from Dust and Grit.

Direct-connected motors are always preferable to belted, if a direct current is available, on account of greater quietness of action. This is due both to the slower speed of the motor and to the absence of belts.

Sufficient speed regulation can be obtained with direct-connected machines, without excessive waste of energy, by the use of a rheostat.

If a direct current is not available, and an alternating current must be used, the advantages of electric driving are greatly reduced, as high-speed motors with belts must be employed, and, furthermore, satisfactory speed regulation is not easily attainable.

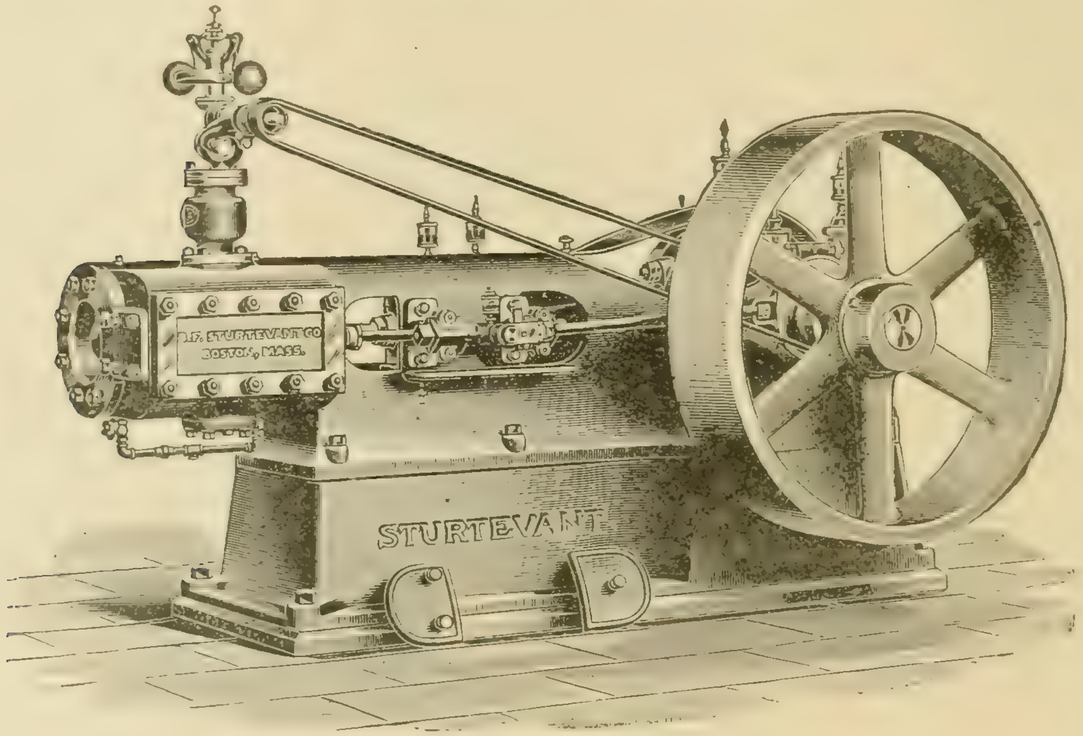


Fig. 154. Horizontal Engine for Fan Use.

Area of Ducts and Flues. With the blower type of fan, the size of the main ducts may be based on a velocity of 1,200 to 1,500 feet per minute; the branches, on a velocity of 1,000 to 1,200 feet per minute, and as low as 600 to 800 feet when the pipes are small. Flue velocities of 500 to 700 feet per minute may be used, although the lower velocity is preferable. The size of the inlet register should be such that the velocity of the entering air will not exceed about 300 feet per minute. The velocity between the inlet windows and the fan or heater should not exceed about 800 feet.

The air-ducts and flues are usually made of galvanized iron, the ducts being run at the basement ceiling. No. 20 and No. 22 iron is used for the larger sizes, and No. 24 to No. 28 for the smaller.

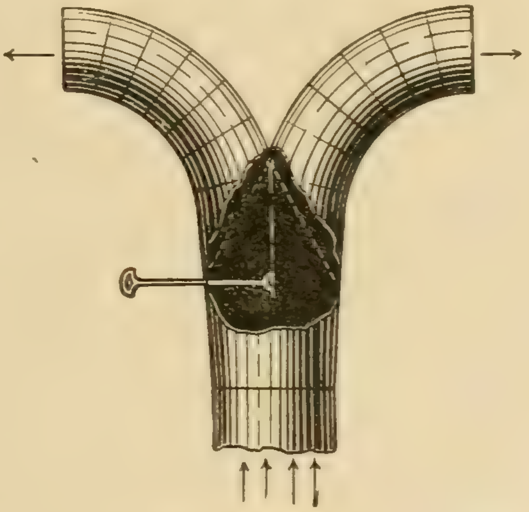


Fig. 155. Adjustable Deflector Placed at Fork of Pipe to Regulate Air-Supply.

Regulating dampers should be placed in the branches leading to each flue, for increasing or reducing the air-supply to the different rooms. Adjustable deflectors are often placed at the fork of a pipe for the same purpose. One of these is shown in Fig. 155.

Fig. 156 illustrates a common arrangement of fan and heater where the type of heater shown in Fig. 138 is used; and Fig. 157 is a self-contained apparatus in which the heater is inclosed in a steel casing.

Factory Heating. The application of forced blast for the warming of factories and shops, is shown in Figs. 158 and 159. The proportional heating surface in this case is generally expressed in the number of cubic feet in the building for each linear foot of 1-inch steam pipe in the heater. On this basis, in factory practice, with all of the air taken from out of doors, there are generally allowed from 100 to 150 cubic feet of space per foot of pipe, according as exhaust or live steam is used, live steam in this case indicating steam of about 80 pounds pressure. If practically all the air is returned from the

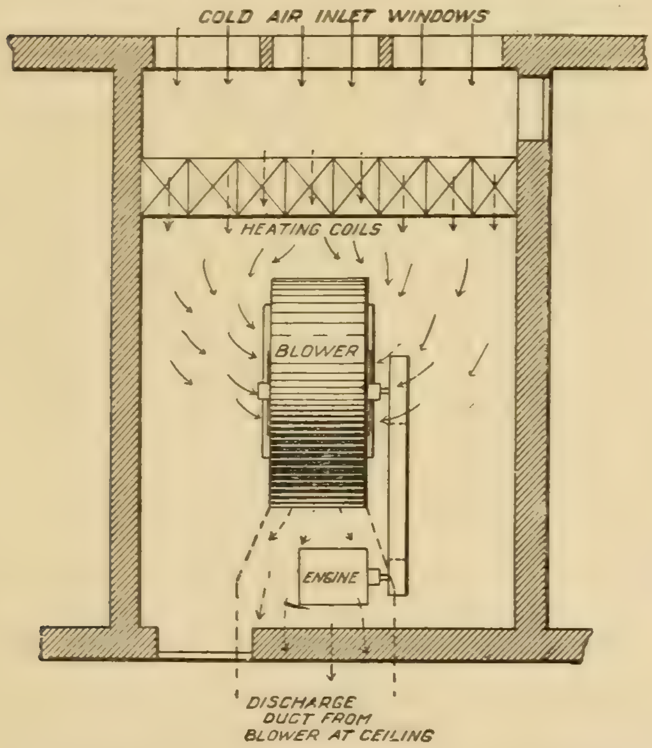


Fig. 156. Common Arrangement of Fan with Heater of Type Shown in Fig. 138.

buildings to the heater, these figures may be raised to about 140 as a minimum, and possibly 200 as a maximum, per foot of pipe. The heaters in Table XXXI may be changed to linear feet of 1 inch pipe by multiplying the numbers in column three (square feet of surface) by three.

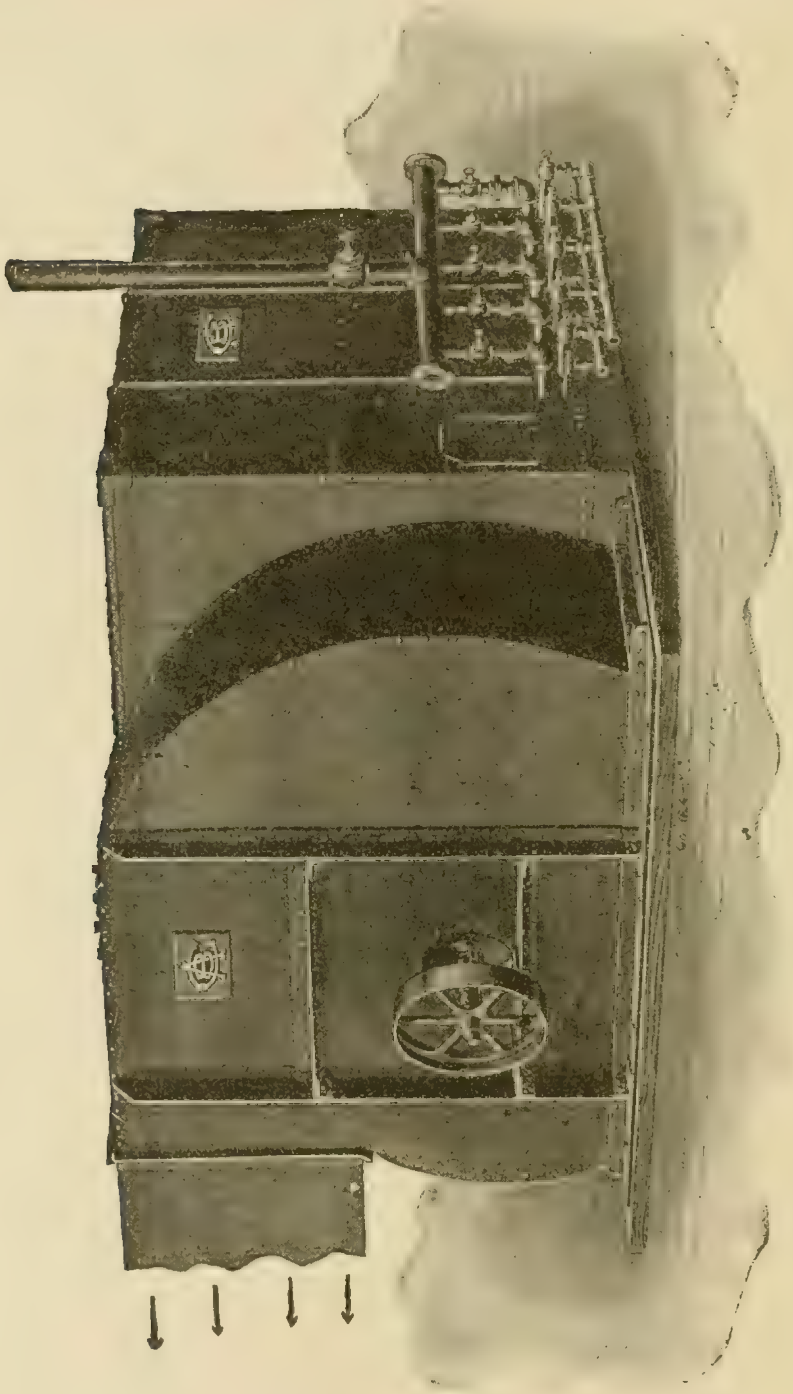


Fig. 157. Self-Contained Heater and Blower in Steel Casing.

EXAMPLES FOR PRACTICE

1. A machine shop 100 feet long by 50 feet wide and having 3 stories, each 10 feet high, is to be warmed by forced blast, using exhaust steam in the heater. The air is to be returned to the heater from the building, and the whole amount contained in the building is to pass through the heater every 15 minutes. What size of blower

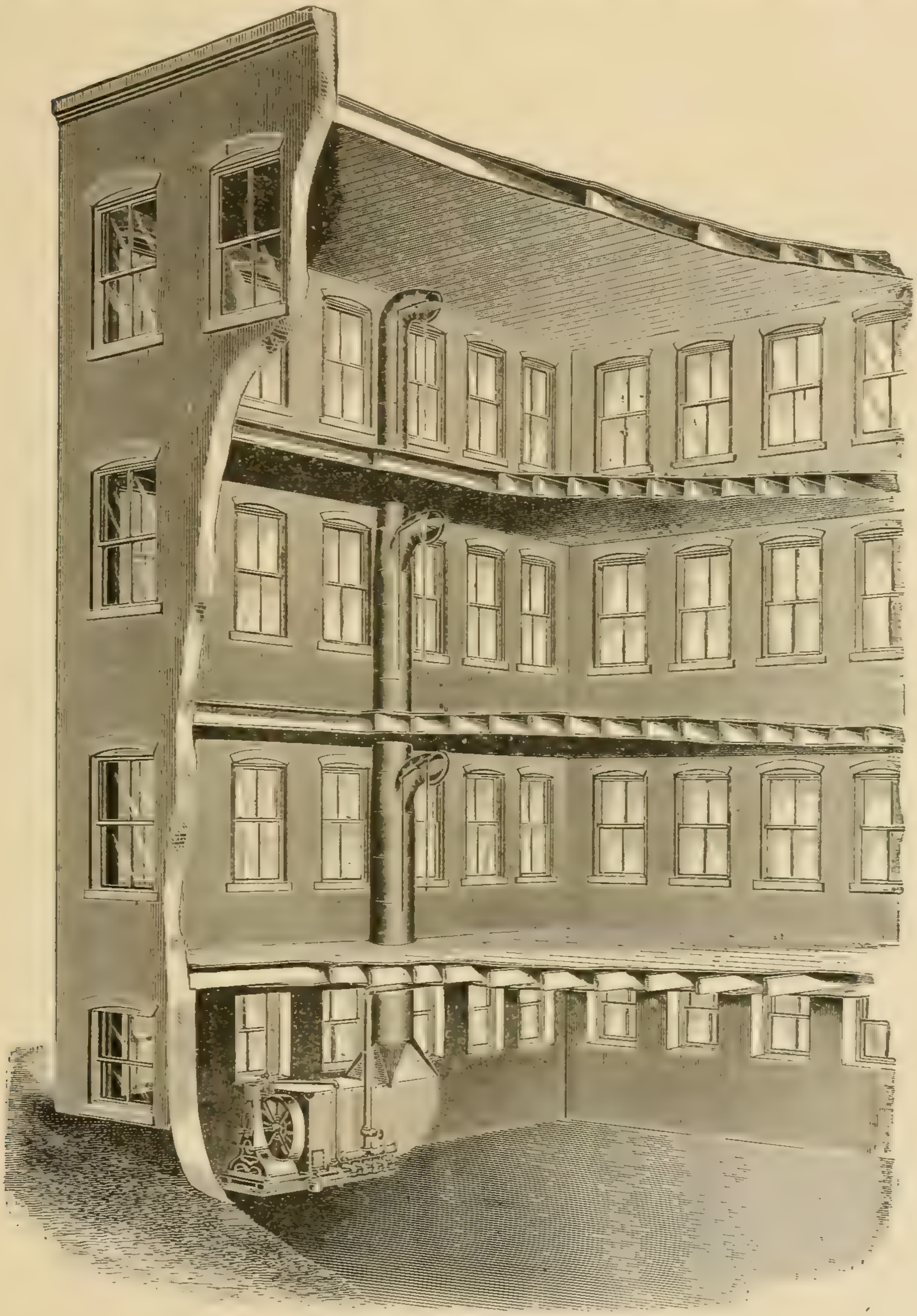


Fig. 158. Illustrating Application of Forced Blast for Warming a Factory.

will be required, and what will be the H. P. of the engine required to run it? How many linear feet of 1-inch pipe should the heater contain?

$$\text{Ans.}\begin{cases}\text{4-foot blower.}\\ \text{6 H. P. engine.}\\ \text{1,071 feet of pipe.}\end{cases}$$

Fig. 159. Centrifugal Blower Producing Forced Blast for Heating a Shop.

2. Find the size of blower, engine, and heater for a factory 200 feet long, 60 feet wide, and having 4 stories, each 10 feet high, using live steam at 80 pounds pressure in the heater, and changing the air every 20 minutes by taking in cold air from out of doors.

$$\text{Ans.}\begin{cases}\text{6-foot blower.}\\ \text{13 H. P. engine.}\\ \text{3,200 feet of pipe.}\end{cases}$$

In using this method of computation, judgment must be employed, which can come only from experience. The figures given are for average conditions of construction and exposure.

Double-Duct System. The varying exposures of the rooms of a school or other building similarly occupied, require that more heat shall be supplied to some than to others. Rooms that are on the south side of the building and exposed to the sun, may perhaps be kept perfectly comfortable with a supply of heat that will maintain a temperature of only 50 or 60 degrees in rooms on the opposite side of the building which are exposed to high winds and shut off from the warmth of the sun.

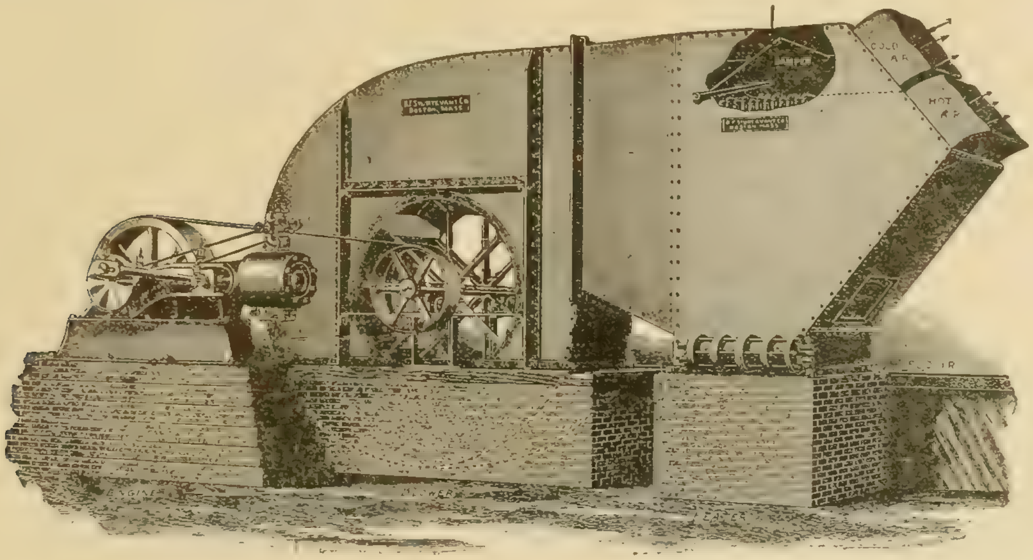


Fig. 160. Hot-Blast Apparatus with Double Duct for Supplying Air at Different Temperatures to Different Parts of a Building.

With a constant and equal air-supply to each room, it is evident that the temperature must be directly proportional to the cooling surfaces and exposure, and that no building of this character can be properly heated and ventilated if the temperature cannot be varied without affecting the air-supply.

There are two methods of overcoming this difficulty:

The older arrangement consists in heating the air by means of a primary coil at or near the fan, to about 60 degrees, or to the minimum temperature required within the building. From the coil it passes to the bases of the various flues, and is there still further heated as required, by secondary or supplementary heaters placed at the base of each flue.

With the second and more recent method, a single heater is employed, and all the air is heated to the maximum required to maintain the desired temperature in the most exposed rooms, while the temperature of the other rooms is regulated by mixing with the hot air a sufficient volume of cold air at the bases of the different flues. This result is best accomplished by designing a hot-blast apparatus so that the air shall be forced, rather than drawn through the heater, and by providing a by-pass through which it may be discharged without passing across the heated pipes.

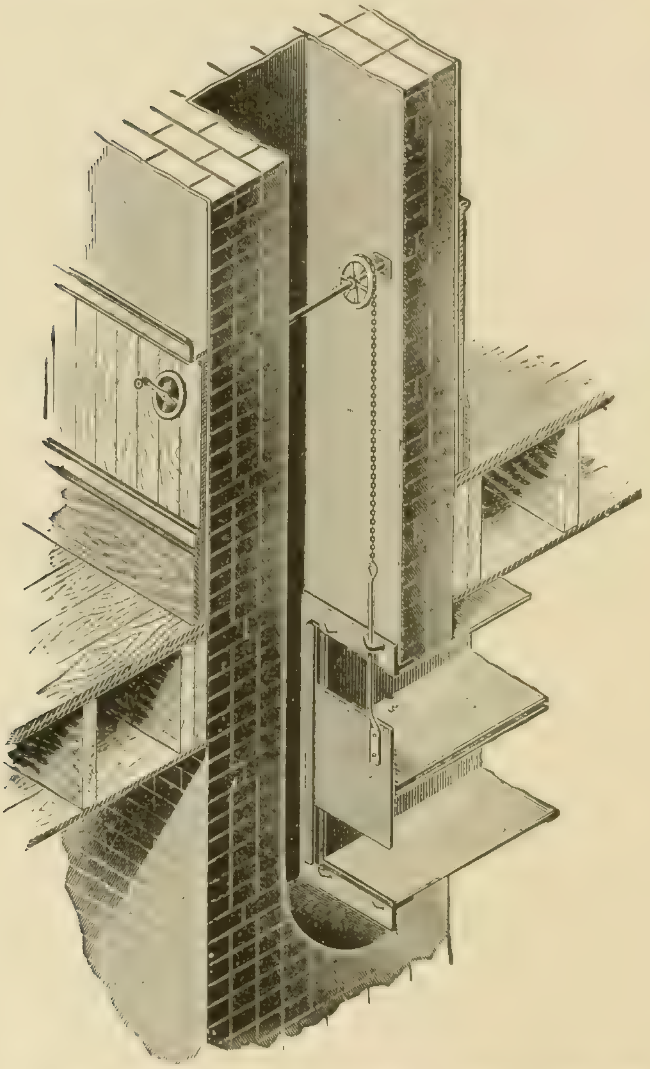


Fig. 161. Mixing Damper for Regulating Temperature of Air Supplied by Double-Duct System.

The passage for the cool air is usually above and separate from the heater pipes, as shown in Fig. 160. Extending from the apparatus is a double system of ducts, usually of galvanized iron, suspended from the ceiling. At the base of each flue is placed a mixing damper, which is controlled by a chain from the room above, and so designed as to admit either a full volume of hot air, a full volume of cool or tempered air, or to mix them in any desired proportion without affecting the resulting total volume delivered to the room. A damper o this form is shown in Fig. 161.

Fig. 162 shows an arrangement of disc fan and heater where the air is first drawn through a tempering coil, then a portion of it forced through a second heater and into the warm-air pipes, while the remainder is by-passed under the heater into the cold-air pipes. Mixing

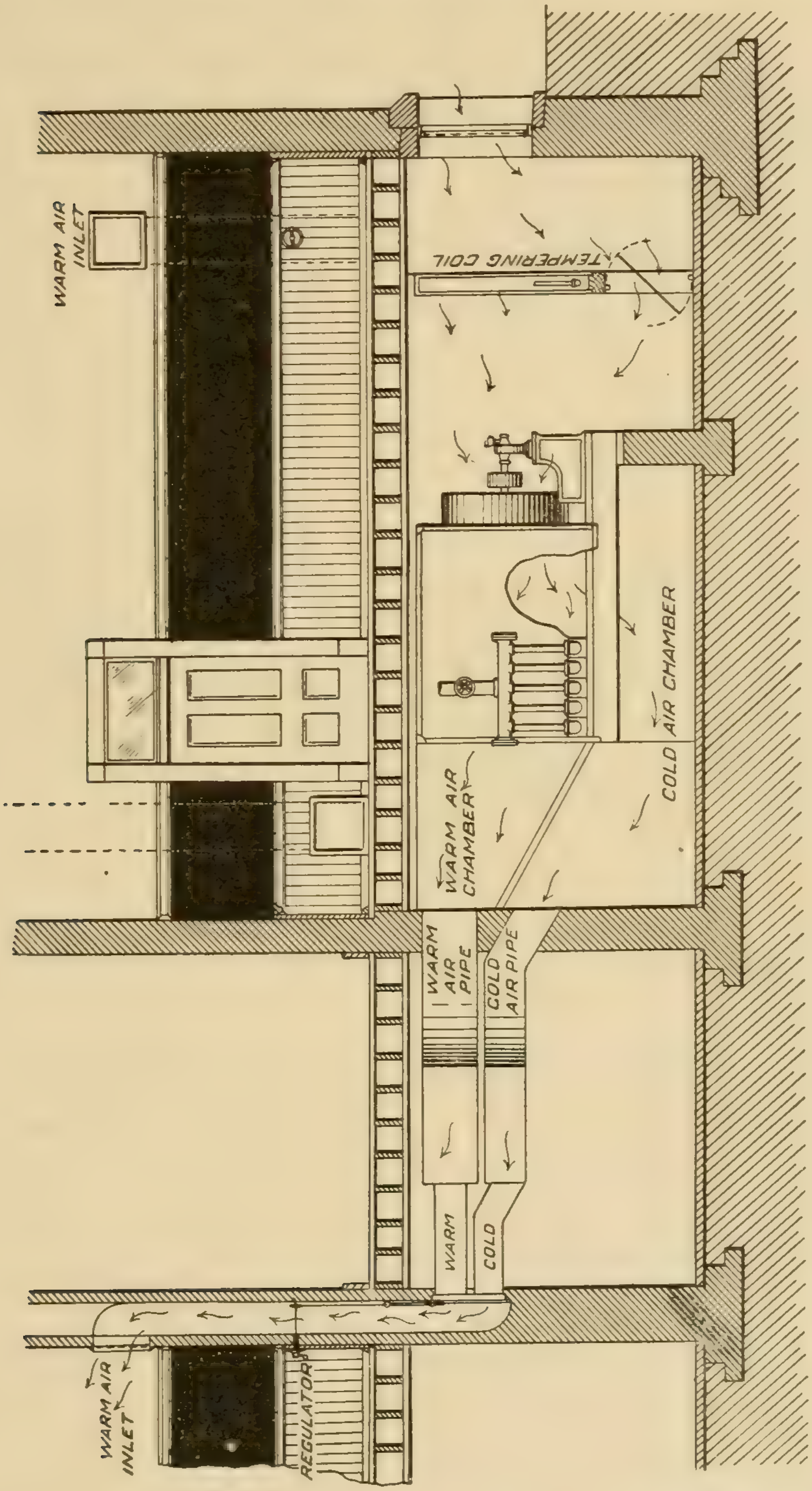


Fig. 162. Warming System Combining Tempering Coil, Disc Fan, Second Heater, and Double Ducts.

dampers are placed at the bases of the flues as already described, to regulate the temperature in different rooms.

ELECTRIC HEATING

Unless electricity is produced at a very low cost, it is not commercially practicable for heating residences or large buildings. The electric heater, however, has quite a wide field of application in heating small offices, bathrooms, electric cars, etc. It is a convenient method of warming rooms on cold mornings in late spring and early fall, when furnace or steam heat is not at hand. It has the special advantage of being instantly available, and the amount of heat can be regulated at will. The heaters are perfectly clean, do not vitiate the air, and are portable.

Electric Heat and Energy. The commercial unit for electricity is one watt for one hour, and is equal to 3.41 B. T. U. Electricity is usually sold on the basis of 1,000 watt-hours (called *Kilowatt-hours*), which is equivalent to 3,410 B. T. U. A watt is the product obtained by multiplying a current of 1 ampere by an electromotive force of 1 volt.

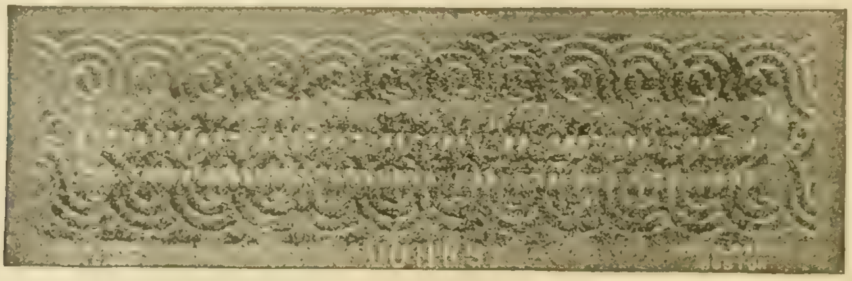


Fig. 163. Electric Car-Heater.

From the above we see that the B. T. U. required per hour for warming, divided by 3,410, will give the kilowatt-hours necessary for supplying the required amount of heat.

Construction of Electric Heaters. Heat is obtained from the electric current by placing a greater or less resistance in its path. Various forms of heaters have been employed. Some of the simplest consist merely of coils or loops of iron wire, arranged in parallel rows, so that the current can be passed through as many coils as are needed to provide the required amount of heat. In other forms, the heating material is surrounded with fire-clay, enamel, or asbestos, and in some cases the material itself has been such as to give considerable resistance to the current. A form of electric car-heater is shown in Fig. 163. Forms of radiators are shown in Figs. 164 and 165.

Calculation of Electric Heaters. The formula for the calculation of electric heaters is

$$H = I^2 R t \times .24,$$

in which

H = Heat, in calories;
I = Current, in amperes;
R = Resistance, in ohms;
t = Time, in seconds.

Examples. What resistance must an electric heater have, to give off 6,000 B. T. U. per hour, with a current of 20 amperes?

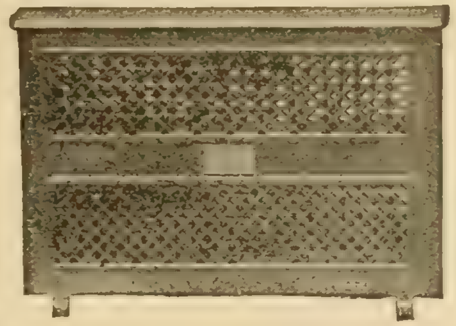


Fig. 164. Electric Radiator.

We have learned that 1 B. T. U. = 252 calories; so, in the present case, 6,000 × 252 = 1,512,000 calories must be provided.

Substituting the known values in the formula, we have

$$1{,}512{,}000 = 20^2 \times R \times 3{,}600 \times .24,$$

from which

$$R = \frac{1{,}512{,}000}{345{,}600} = 4.37 \text{ ohms.}$$

A heater having a resistance of 3 ohms is to supply 3,000 B. T. U. per hour. What current will be required?

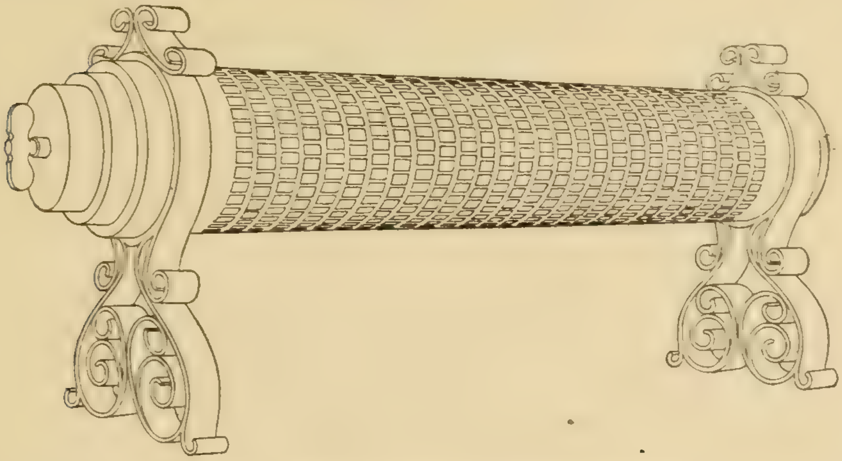


Fig. 165. Another Form of Electric Radiator.

3,000 × 252 = 756,000 calories. Substituting the known values in the formula, and solving for I, we have

$$756{,}000 = I^2 \times 3 \times 3{,}600 \times .24,$$

from which

$$I = \sqrt{291.6} = 17 + \text{amperes.}$$

Connections for Electric Heaters. The method of wiring for electric heaters is essentially the same as for lights which require the same amount of current. A constant electromotive force or voltage is maintained in the main wire leading to the heaters. A much less voltage is carried on the return wire, and the current in passing through the heater from the main to the return, drops in voltage or pressure. This drop provides the energy which is transformed into heat.

The principle of electric heating is much the same as that involved in the non-gravity return system of steam heating. In that system, the pressure on the main steam pipes is that of the boiler, while that on the return is much less, the reduction in pressure occurring in the passage of the steam through the radiators; the water of condensation is received into a tank, and returned to the boiler by a pump.

In a system of electric heating, the main wires must be sufficiently large to prevent a sensible reduction in voltage or pressure between the generator and the heater, so that the pressure in them shall be substantially that in the generator. The pressure or voltage in the main return wire is also constant, but very low, and the generator has an office similar to that of the steam pump in the system just described—that is, of raising the pressure of the return current up to that in the main. The power supplied to the generator can be considered the same as the boiler in the first case. All the current which passes from the main to the return must flow through the heater, and in so doing its pressure or voltage falls from that of the main to that of the return.

From the generator shown in Fig. 166, main and return wires are run the same as in a two-pipe system of steam heating, and these are proportioned to carry the required current without sensible drop or loss of pressure. Between these wires are placed the various heaters, which are arranged so that when electric connection is made they draw the current from the main and discharge it into the return wire. Connections are made and broken by switches, which take the place of valves on steam radiators.

Cost of Electric Heating. The expense of electric heating must in every case be great, unless the electricity can be supplied at an exceedingly low cost. Estimated on the basis of present practice, the average transformation into electricity does not account for more than 4 per cent of the energy in the fuel which is burned in the furnace. Although under best conditions 15 per cent has been realized, it would not be safe to assume that in ordinary practice more than 5 per cent could be transformed into electrical energy. In heating with steam, hot water, or hot air, the average amount utilized will probably be about 60 per cent, so that the expense of electrical heating is approximately from 12 to 15 times greater than by these methods.

TEMPERATURE REGULATORS

The principal systems of automatic temperature control now in use, consist of three essential features; *First*, an air-compressor, reservoir, and distributing pipes; *second*, thermostats, which are placed in the rooms to be regulated; and *third*, special diaphragm or pneumatic valves at the radiators.

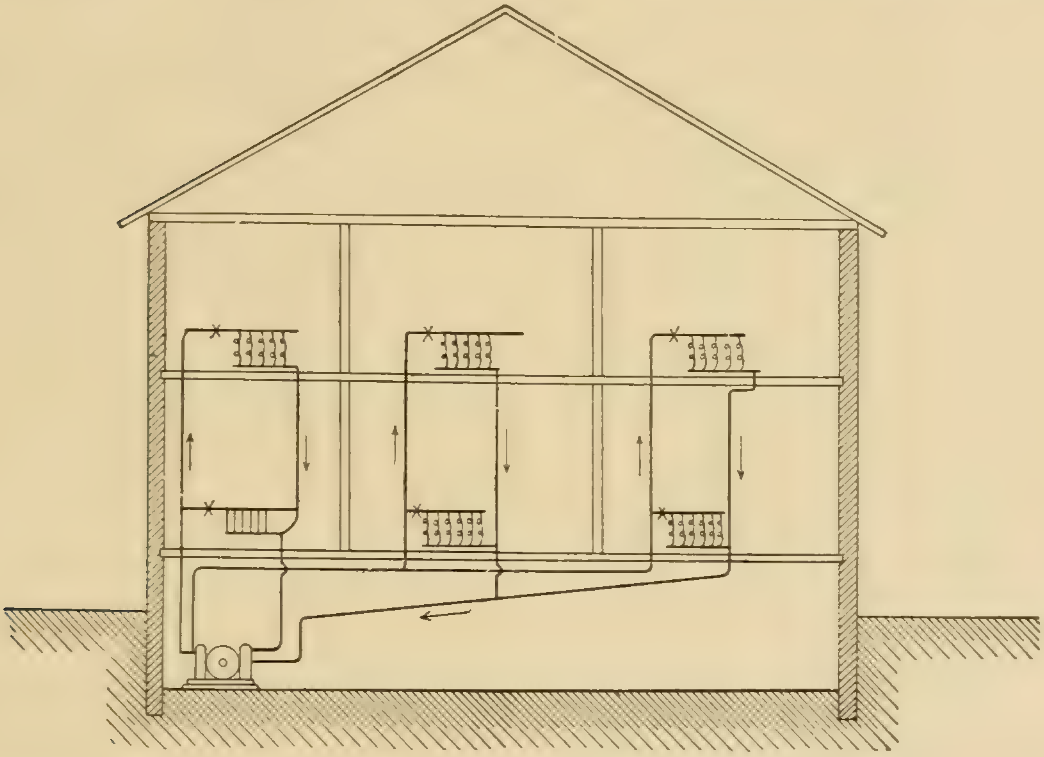


Fig. 166. General System of Wiring a House for Electric Heating.

The *air-compressor* is usually operated by water-pressure in small plants and by steam in larger ones; electricity is used in some cases. Fig. 167 shows a form of water compressor. It is similar in principle to a direct-acting steam pump, in which water under pressure takes the place of steam. A piston in the upper cylinder compresses the air, which is stored in a reservoir provided for the purpose. When the pressure in the reservoir drops below a certain point, the compressor is started automatically, and continues to operate until the pressure is brought up to its working standard.

A *thermostat* is simply a mechanism for opening and closing one or more small valves, and is actuated by changes in the temperature of the air in which it is placed. Fig. 168 shows a thermostat in which the valves are operated by the expansion and contraction of the metal strip *E*. The degree of temperature at which it acts may be adjusted by throwing the pointer at the bottom one way or the other. Fig. 169 shows the same thermostat with its ornamental

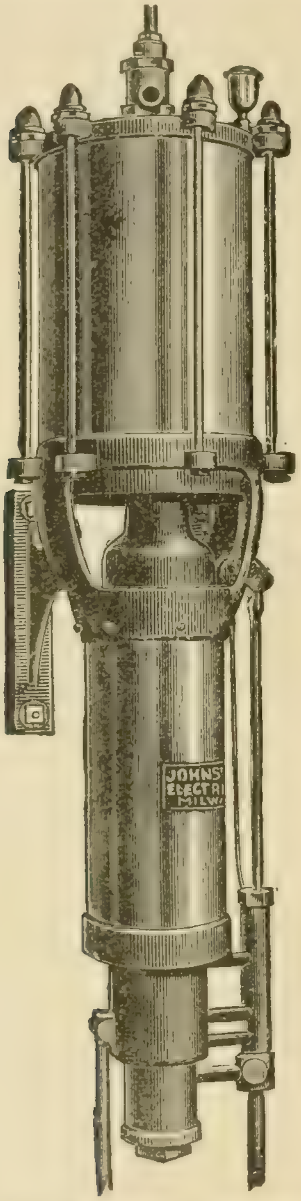


Fig. 167. Air-Compressor Operated by Water Pressure, Automatically Controlled, and Operating to Regulate Temperature by Controlling Radiator Valves.

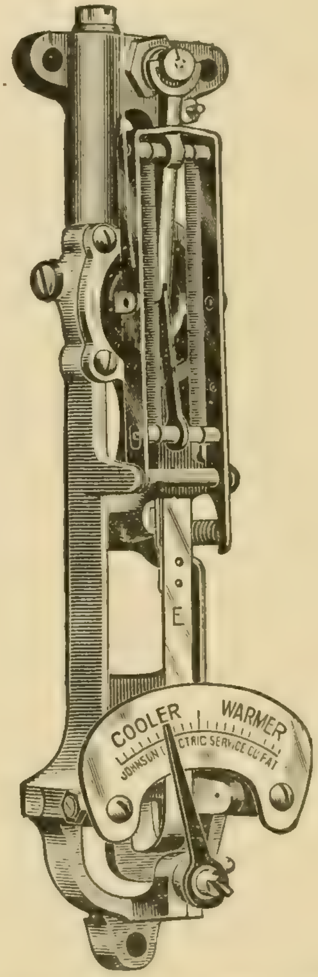


Fig. 168. Thermostat Controlling Valves on Radiators, and Operating through Expansion or Contraction of Metal Strip *E*.

casing in place. The thermostat shown in Fig. 170 operates on a somewhat different principle. It consists of a vessel separated into two chambers by a metal diaphragm. One of these chambers is partially filled with a liquid which will boil at a temperature below that desired in the room. The vapor of the liquid produces considerable pressure at the normal temperature of the room, and a slight increase of heat crowds the diaphragm over and operates the small valves in a manner similar to that of the metal strip in the case just described.

The general form of a *diaphragm valve* is shown in Fig. 171. These replace the usual hand-valves at the radiators. They are similar in construction to the ordinary globe or angle valve, except that the stem slides up and down instead of being threaded and running in a nut. The top of the stem connects with a flat plate, which rests against a rubber diaphragm. The valve is held open by a spring, as shown, and is closed by admitting compressed air to the space above the diaphragm.

In connecting up the system, small concealed pipes are carried from the air-reservoir to the thermostat, which is placed upon an inside wall of the room, and from there to the diaphragm valve at the radiator. When the temperature of the room reaches the maximum point for which the thermostat is set, its action opens a small valve and admits air-pressure to the diaphragm, thus closing off the

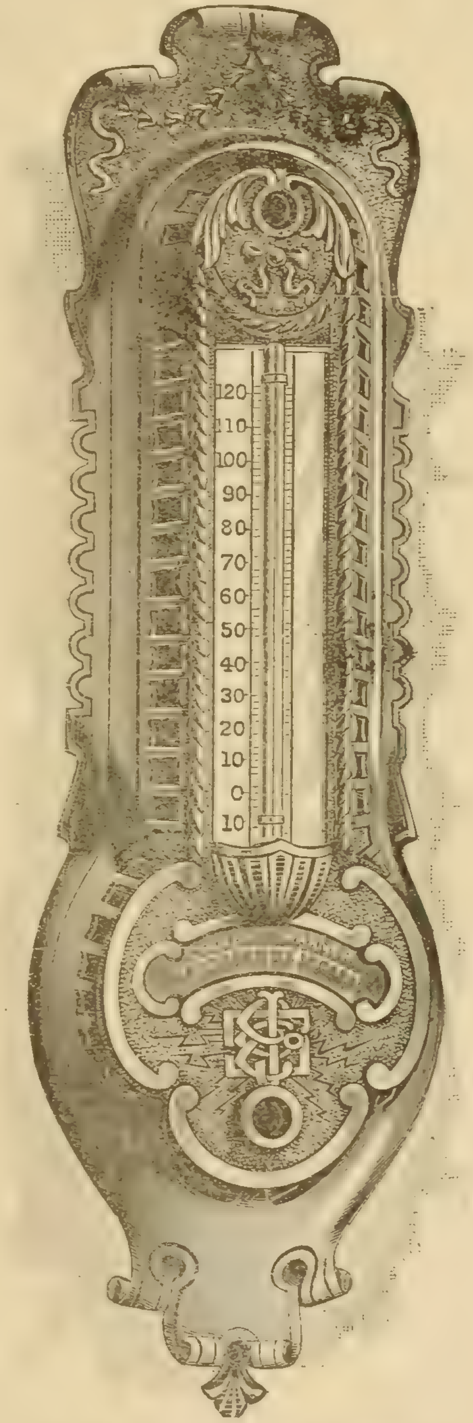


Fig. 169. Thermostat of Fig. 168 in Ornamental Casing.

steam from the radiator. When the temperature falls, the thermostat acts in the opposite manner, and shuts off the air-pressure from the diaphragm valve, at the same time opening a small exhaust which allows the air above the diaphragm to escape. The pressure being removed, the valve opens and again admits steam to the radiator.

Diaphragm Motors. Dampers are operated pneumatically in a similar manner to steam valves. A *diaphragm motor*, so called, is acted upon by the air-pressure; and this lifts a lever which is properly connected to the damper by means of chains or levers, thus securing the desired movement.

Dampers. When mixing dampers are operated pneumatically, a specially designed thermostat for giving a graduated movement to the damper should be used. By this arrangement the damper is held in such a position at all times as to admit the proper proportions of hot and cold or tempered air for producing the desired temperature in the room with which it is connected.

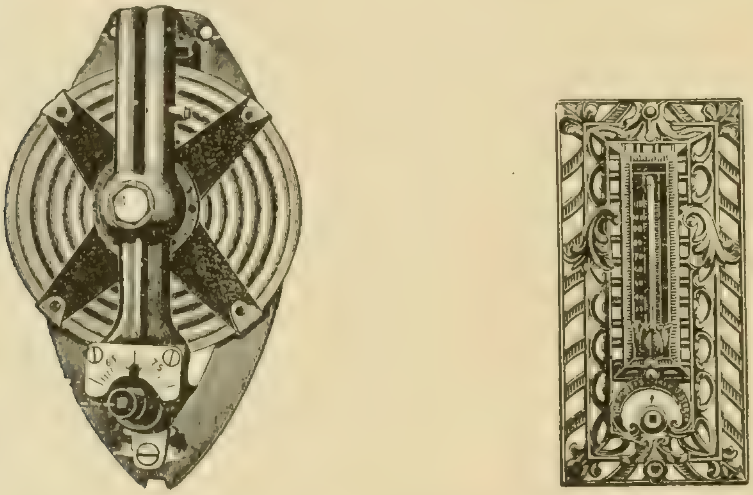
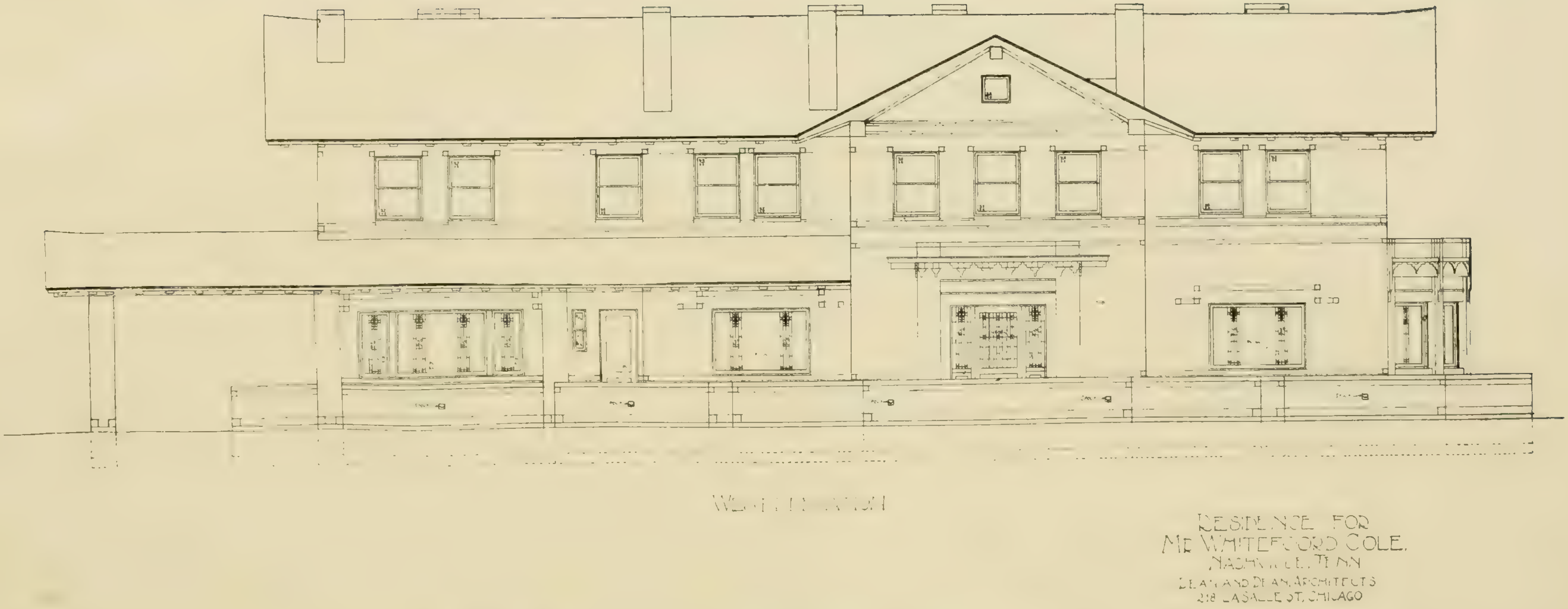


Fig. 170. Thermostat Operating through Expansion or Contraction of the Vapor of a Volatile Liquid.

Large dampers which are to be operated pneumatically, should be made up in sections or louvres. Dampers constructed in this manner are handled much more easily than when made in a single piece.

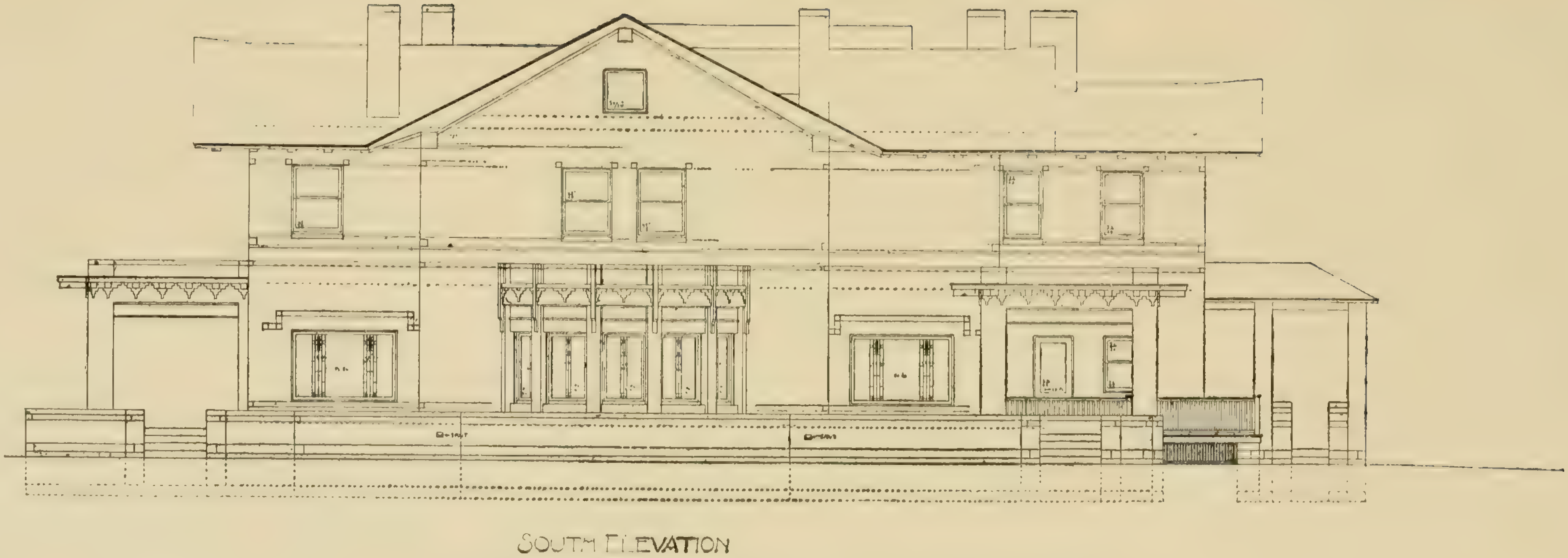
It often happens, in large plants, that there are valves and dampers in places which are not easily reached for hand manipulation. These may be provided with diaphragms and connected with the air-pressure system for operation by hand-switches or cocks



RESIDENCE FOR MR. WHITEFOORD COLE, NASHVILLE, TENN.

Dean & Dean, Architects, Chicago, Ill.

South Elevation Shown on Opposite Page. For Plan and Interior Details, See Page 218.



RESIDENCE FOR MR. WHITEFOORD COLE, NASHVILLE, TENN.

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West Elevation Shown on Opposite Page. For Plan and Interior Details, See Page 218.

conveniently located at some central point in the basement or boiler room.

Telethermometer. This is a device for indicating on a dial at some central point the temperature of various rooms or ducts in different parts of a building. A special *transmitter* is placed in each of the rooms and electrically connected with a central switchboard. Then, by means of suitable switches, any room may be thrown in circuit with the *recorder*, and the temperature existing in the room at that time read from the dial.

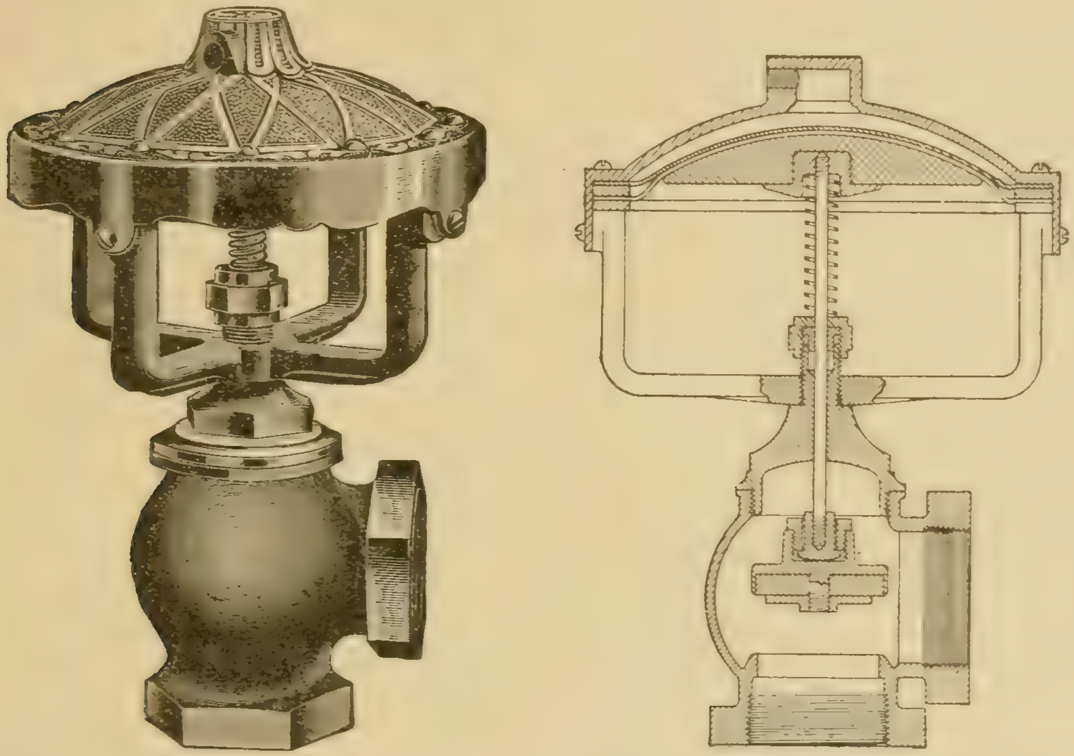


Fig. 171. Exterior View. and Section Showing Interior Mechanism of Diaphragm Valve.

Humidostat. The *humidostat* is a device to be placed in one or more rooms of a building for maintaining an even percentage of moisture in the air. The apparatus consists of two essential parts—the *humidostat* and the *humidifier*. The former corresponds to the thermostat in a system of temperature control, and operates a pneumatic valve or other mechanism connected with the humidifier when the percentage of moisture rises above or falls below certain limits. The operating medium is compressed air, the same as for temperature control; and the two devices are usually connected with the same pressure system.

The normal moisture of a room is 70 per cent, and should never exceed that. In cold weather it will be necessary to reduce the amount of moisture somewhat, owing to the "sweating" of walls and windows.

The method of moistening the air will depend somewhat upon circumstances. If the air for ventilation is delivered to the rooms at a temperature not exceeding 70 degrees, the humidifier is best placed in the main air-duct. If the air enters at a higher temperature, the humidifier must be located in the same room with the humidostat.

The moistener or humidifier may be of any one of several forms. Where steam heating is used, and where the steam is clean and odorless and free from oil from engines, a perforated pipe (or pipes) in the air-duct is the simplest and best humidifier. The outlets are properly adjusted, and then the humidostat shuts off and lets on the steam as required. Sometimes a water spray, particularly of warm water, may be used in place of steam. When neither steam jet nor water spray is advisable, an evaporating pan containing a steam coil may be used, the humidostat controlling the steam to the coil, and the water-level in the pan being kept constant by means of a ball-cock.

AIR=FILTERS AND AIR=WASHERS

In cases where the air for ventilating purposes is likely to contain soot or street dust, it is desirable to provide some form of filter for purifying it before delivering to the rooms. If the air-quantity is small and there is plenty of room between the inlet windows and the fan, screens of light cheesecloth may be used for this purpose. The cloth should be tacked to light but substantial wooden frames, which can be easily removed for frequent cleaning. These screens are usually set up in "saw-tooth" fashion in order to give as much surface as possible in the least space.

Another arrangement, used in case of large volumes of air, is to provide a number of light cloth bags of considerable length, through which the air is drawn before reaching the heater. These are fastened to a suitable frame or partition for holding them open. The great objection to filters of this kind is their obstruction to the passage of the air, especially when filled with dust, the frequent intervals at which they should be cleaned, and the great amount of filtering surface required.

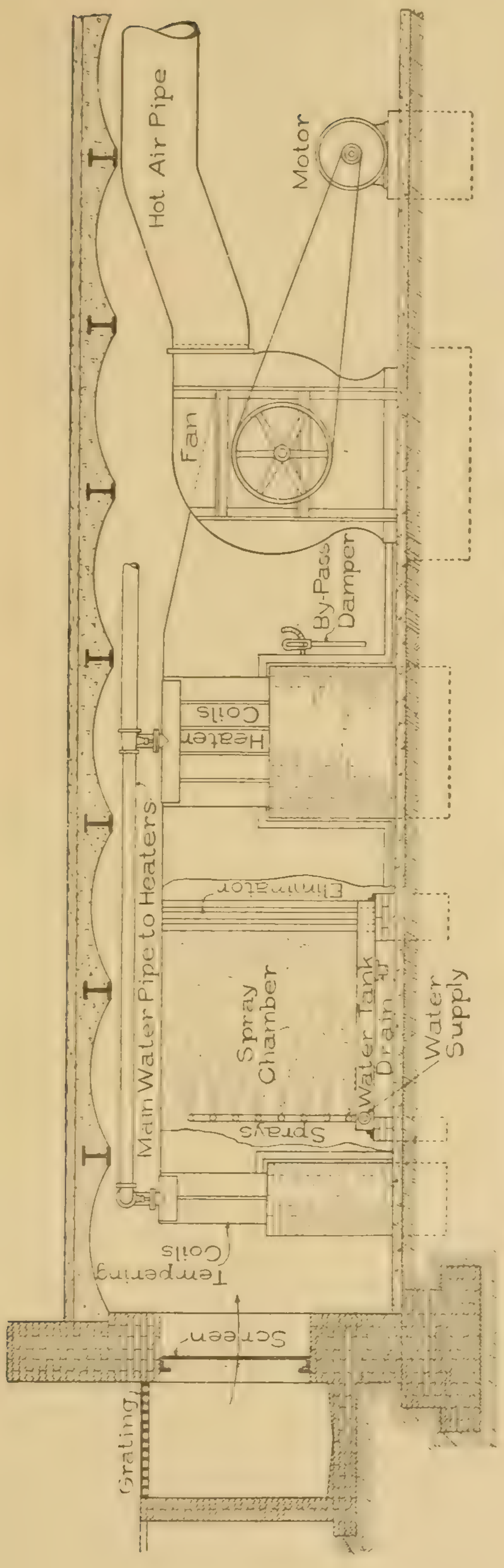


Fig. 172. One Form of Spray Filter or Air-Washer, for Removing Dust or Soot from Air Required for Ventilation.

An apparatus which is coming quite generally into use for this purpose, and which does away with the disadvantages noted above, is the *spray filter* or *air-washer,* one form of which is shown in Fig. 172. Air enters as indicated, and first passes through a tempering coil to raise it above the freezing point in winter weather; then passes through the spray-chamber, where the dirt is removed; then through an eliminator for removing the water; and then through a second heater on its way to the fan.

The water is forced through the spray-heads by means of a small centrifugal pump, either belted to the fan shaft or driven by an independent motor.

HEATING AND VENTILATION OF VARIOUS CLASSES OF BUILDINGS

The different methods used in heating and ventilation, together with the manner of computing the various proportions of the apparatus, having been taken up, the application of these systems to the different classes of buildings will now be considered briefly.

School Buildings. For school buildings of small size, the furnace system is simple, convenient, and generally effective. Its use is confined as a general rule to buildings having not more than six or eight rooms. For large ones this method must generally give way to some form of indirect steam system with one or more boilers, which occupy less space, and are more easily cared for than a number of furnaces scattered about in different parts of the basement. As in all systems that depend on natural circulation, the supply and removal of air is considerably affected by changes in the outside temperature and by winds.

The furnaces used are generally built of cast iron, this material being durable, and easily made to present large and effective heating surfaces. To adapt the larger sizes of house-heating furnaces to schools, a much larger space must be provided between the body and the casing, to permit a sufficient volume of air to pass to the rooms. The free area of the air-passage should be sufficient to allow a velocity of about 400 feet per minute.

The size of furnace is based on the amount of heat lost by radiation and conduction through walls and windows, *plus* that carried away by air passing up the ventilating flues. These quantities may be computed by the usual methods for "loss of heat by conduction through walls," and "heat required for ventilation." With more regular and skilful attendance, it is safe to assume a higher rate of combustion in schoolhouse heaters than in those used for warming residences. Allowing a maximum combustion of 6 pounds of coal per hour per square foot of grate, and assuming that 8,000 B. T. U. per pound are taken up by the air passing over the furnace, we have 6 × 8,000 = 48,000 B. T. U. furnished per hour per square foot of grate. Therefore, if we divide the total B. T. U. required for both warming and ventilation by 48,000, it will give us the necessary grate surface in square feet. It has been found in practice that a furnace with a firepot 32 inches in diameter, and having ample heating surface, is capable of heating two 50-pupil rooms in zero weather. The sizes of ducts and flues may be determined by rules already given under furnace and indirect steam heating.

The velocity of the warm air within the uptake flues depends upon their height and the difference in temperature between the warm air within the flues and the cold air outside. The action of the wind also affects the velocity of air-flow. It has been found by experience that flues having sectional areas of about 6 square feet for first-floor rooms, 5 square feet for the second floor, and 4½ square feet for the third, will be of ample size for standard classrooms seating from 40 to 50 pupils in primary and grammar schools. These sizes may be used for both furnace and indirect gravity steam heating.

The vent flues may be made 5 square feet for the first floor, and 6 square feet for the second and third floors. They may be arranged in banks, and carried through the roof in the form of large chimneys, or may be carried to the attic space and there gathered by means of galvanized-iron ducts connecting with roof vents of wood or copper construction.

In order to make the vent flues "draw" sufficiently in mild or heavy weather, it is necessary to provide some means for warming the air within them to a temperature somewhat above that of the rooms with which they connect. This may be done by placing a small stove made specially for the purpose, at the base of each flue. If this is done, it is necessary to carry the air down and connect with the flue just below the stove.

The cold-air supply duct to each furnace should be made ¾ the size of all the warm-air flues if free from bends, or the full size if obstructed in any way.

The inlet and outlet openings from the rooms into the flues, are commonly provided with grilles of iron wire having a mesh of 2 to 2½ inches. Both flat and square wire are used for this purpose. Mixing dampers for regulating the temperature of the rooms should be provided for each flue. The effectiveness of these dampers will depend largely upon their construction; and they should be made tight against cold-air leakage, by covering the surfaces or flanges against which they close with some form of asbestos felting. Both inlet and outlet gratings should be provided with adjustable dampers. One of the disadvantages of this system is the delivery of all the heat to the room from a single point, and this not always in a position to give the best results. The outer walls are thus left unwarmed, except as the heat is diffused throughout the room by air-currents. When there is considerable glass surface, as in most of our modern schoolrooms, draughts and currents of cold air are frequently found along the outside walls.

The indirect gravity system of steam heating comes next in cost of installation. One important advantage of this system over furnace heating comes from the ability to place the heating coils at the base of the flues, thus doing away with horizontal runs of air-pipe, which are required to some extent in furnace heating. The warm-air currents in the flues are less affected by variations in the direction and force of the wind where this construction is possible, and this is of much importance in exposed locations.

The method of supplying cold air to the coils or heaters is important, and should be carefully worked out. The supply should be taken from at least two sides of the building, or, if possible, from all four sides. When it is taken from four sides, each inlet should be made large enough to supply one-half the amount, or, in other words, any two should give the total quantity required. It is often possible to arrange the flues in groups so that all the heating stacks may be placed in two or more cold-air chambers, depending upon the size of the building. A cold-air trunk line may be run through the center of the basement, connecting with the outside on all four sides, and having branches supplying each cold-air chamber.

Cast-iron pin-radiators are particularly adapted to this class of work.

The *School-Pin*, having a section about 10 inches in depth and rated at 15 square feet of heating surface per section, is used quite extensively for this purpose. Stacks containing about 240 square feet of surface for southerly rooms, and 260 for those having a northerly exposure, have been found ample for ordinary conditions in zero weather.

A very satisfactory arrangement is the use of indirect heaters for warming the air needed for ventilation, and the placing of direct radiation in the rooms for heating purposes. The general construction of the indirect stacks and flues may be the same; but the heating surface can be reduced, as the air in this case must be raised only to 70 or 75 degrees in zero weather, the heat to offset that lost by conduction, etc., through walls and windows being provided by the direct surface. The mixing dampers may be omitted, and the temperature of the room regulated by opening or closing the steam valves on the direct coils, which should be done automatically. The direct-heating surface, which is best made up of lines of 1¼-inch pipe, should be placed along the outer walls beneath the windows This supplies heat where most needed, and does away with the tendency to draughts. In mild weather, during the spring and fall, the indirect heaters may prove sufficient for both ventilation and warming.

Where direct radiation is placed in the rooms, the quantity of heat supplied is not affected by varying wind conditions, as is the case in indirect heating. Although the air-supply may be reduced at times, the heat quantity is not changed. Direct radiation has the disadvantage of a more or less unsightly appearance, and architects and owners often object to the running of mains or risers through the rooms of the building. Air-valves should always be provided with drip connections carried to a sink or dry well in the basement.

When circulation coils are used, a good method of drainage is to carry separate returns from each coil to the basement, and to place the air-valves in the drops just below the basement ceiling. A check-valve should be placed below the water-line in each return.

The gravity system has the fault of not supplying a uniform quantity of air under all conditions of outside temperature, the same as a furnace, but when properly arranged, may be made to give quite satisfactory results.

The fan or blower system for ventilation, with direct radiation in the rooms for warming, is considered to be one of the best possible arrangements.

In designing a plant of this kind, the main heating coil should be of sufficient size to warm the total air-supply to 70 or 75 degrees in the coldest weather, and the direct surface should be proportioned for heating the building independently of the indirect system. Automatic temperature regulation should be used in connection with systems of this kind, by placing pneumatic valves on the direct radiation. It is customary to carry from 3 to 8 pounds pressure on the direct system, and from 8 to 15 pounds on the main coil, depending upon the outside temperature. The foot-warmers, vestibule, and office heaters should be placed on a separate line of piping, with separate returns and trap, so that they can be used independently of the rest of the building if desired. Where there is a large assembly hall, it should be arranged so that it can be both warmed and ventilated when the rest of the building is shut off. This can be done by a proper arrangement of valves and dampers.

When different parts of the system are run on different pressures, the returns from each should discharge through separate traps into a receiver having connection with the atmosphere by means of a vent pipe. Fig. 173 shows a common arrangement for the return connections in a combination system of this kind. The different traps discharge into the vented receiver as shown; and the water is pumped back to the boiler automatically when it rises above a given level in the receiver, a pump governor being used to start and stop the pumps as required.

A water-level or seal of suitable height is maintained in the main returns, by placing the trap at the required elevation and bringing the returns into it near the bottom; a balance pipe is connected with the top for equalizing the pressure, the same as in the case of a pump governor. Sometimes a fan is used with the heating coils placed at the base of the flues, instead of in the rooms. Where this is done the radiating surface may be reduced about one-half. This system is less expensive to install, but has the disadvantage of removing the heating surface from the cold walls, where it is most needed.

With a blower type of fan, the size of the main ducts may be based on a velocity of from 1,000 to 1,200 feet per minute, and the branches on a velocity of 800 to 1,000 feet per minute.

The velocity in the vertical flues may be from 600 to 700 feet per minute, although the lower velocity is preferable.

The size of the inlet registers should be such that the velocity of the entering air will not exceed 350 to 400 feet per minute.

When the air is delivered through a register at the high velocities mentioned, some means must be provided for diffusing the entering current, in order to prevent disagreeable draughts. This is usually accomplished by the use of deflecting blades of galvanized iron, set in a vertical position and at varying angles, so that the air is thrown towards each side as it issues from the register. The size of the vent flues should be about the same as for a gravity system—that is, about 6 square feet for a standard classroom, and in the same proportion for smaller rooms.

Vent-flue heaters are not usually required in connection with a fan system, as the force of the fan is sufficient to supply the required

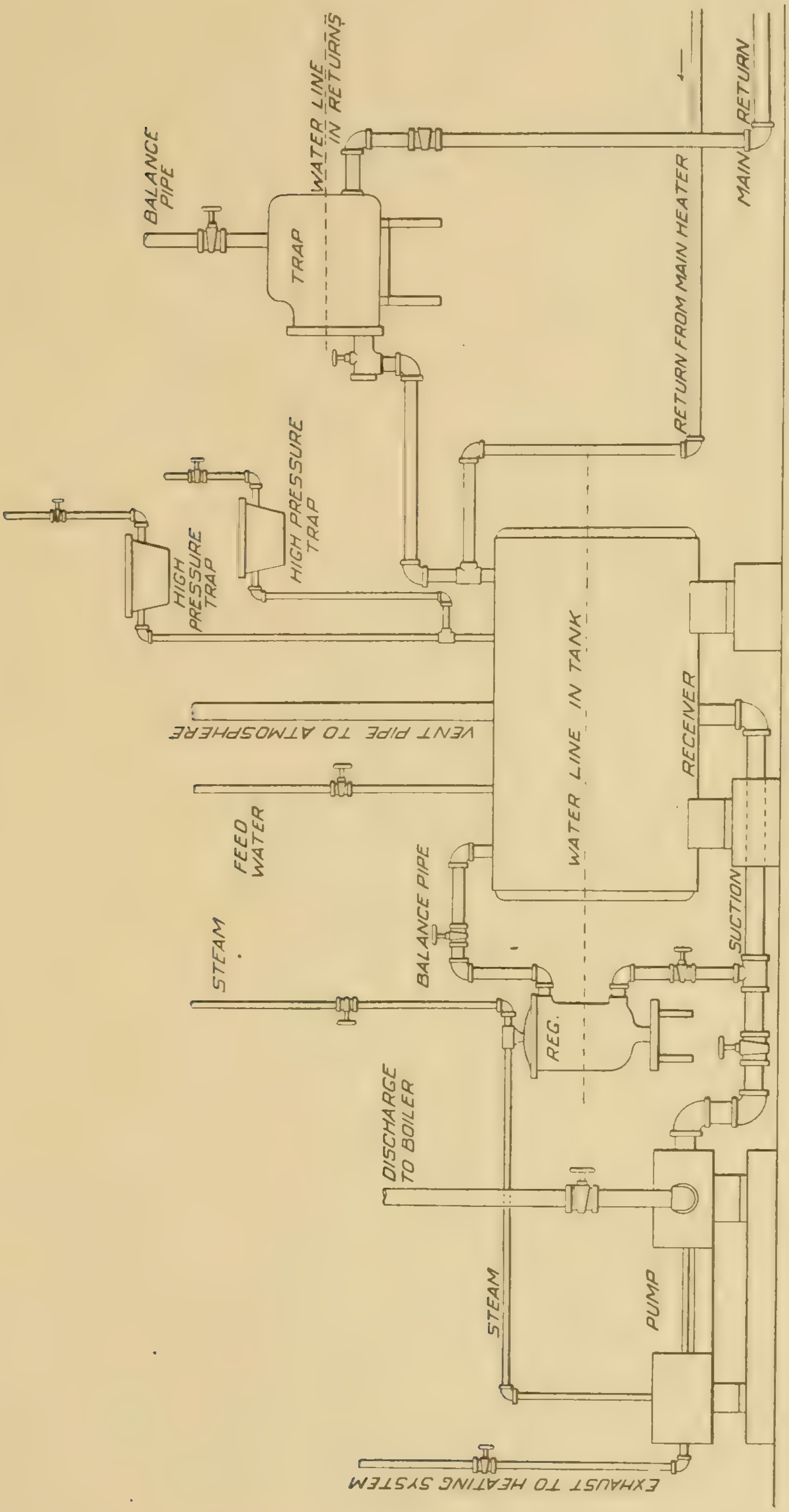


Fig. 173. General Arrangement of Return Connections Especially Adapted to Large Buildings where Different Parts of the Heating System are under Different Pressures.

quantity of air at all times without the aspirating effect of the vent flues.

The method of piping shown in Fig. 173 applies especially to buildings of large size. In the case of medium-sized buildings, it is often possible to use pin radiation for the main heater, placing the same well above the water-line of the boilers and thus returning the condensation by gravity, without the use of pumps or traps. When this arrangement is used, an engine with a large cylinder should be employed, so that the steam pressure will not exceed 15 or 18 pounds, and the whole system, including the direct surface, may be run upon the same system.

This is a very simple arrangement, and is adapted to all buildings of small and medium size where the heater can be placed at a sufficient height above the boilers.

Temperature control is usually secured automatically by placing pneumatic valves upon either the direct or supplementary heaters. Mixing dampers are sometimes used instead, in the latter case. Every fan system should be provided with a thermometer of large size for indicating the temperature of the air in the main duct just beyond the fan.

The ventilation of the toilet-rooms of a school building is a matter of the greatest importance. The first requirement is that the air-movement shall be *into* these rooms from the corridors instead of outward. To obtain this result, it is necessary to produce a slight vacuum within, and this cannot well be done if fresh air is forced into them.

One of the most satisfactory arrangements is to provide exhaust ventilation only, and to remove the greater part of the air through local vents connecting with the fixtures.

Hospitals. The best system for heating and ventilating a hospital depends upon the character and arrangement of the buildings. It is desirable in all cases to do the heating from a central plant, rather than to carry fires in the separate buildings, both on account of economy and for cleanliness.

In the case of small cottage hospitals with two or three buildings placed close together, indirect hot water affords a desirable system for the wards, with direct heat for the other rooms; but where there are several buildings, and especially if they are some distance apart, it becomes necessary to substitute steam unless the water is pumped through the mains. For large city buildings, a fan system is always desirable.

If the building is tall compared with its ground area, so that the horizontal supply ducts will be comparatively short, the double-duct system may be used with good results. Where the rooms are of good size, and the number of supply flues not great, the use of supplementary heaters at the bases of the flues makes a satisfactory arrangement. Direct radiation should never be used in the wards when it can be avoided, even in connection with an independent air-supply, as it offers too great an opportunity for the accumulation of dust in places which are difficult to reach.

It is common to provide from 80 to 100 cubic feet of air per minute per patient in ordinary wards, and from 100 to 120 cubic feet in contagious wards.

The usual ward building of a modern cottage-hospital generally contains a main ward having from 8 to 12 beds, and a number of private rooms of one bed each.

In addition to these, there are a diet kitchen, duty-room, toilet-rooms, bathrooms, linen-closets, and lockers.

For moderately sheltered locations, 30 square feet of indirect steam radiation has been found sufficient in zero weather for a single ward with one exposed wall and a single window, when upon the south side of the building.

For northerly rooms, 40 square feet should be used. In exposed locations, the heaters may be made 40 and 50 square feet for north and south rooms respectively. The standard pin-radiators rated at 10 square feet of heating surface per section, are commonly used for this purpose. In case hot water is used, the same number of sections of the deep-pin pattern rated at 15 square feet each may be employed, making a total of 45 and 60 square feet per room. For corner rooms having two exposed walls and two windows, the amount of radiation should be increased about 50 per cent over that given above.

The wards are usually furnished with fireplaces which provide for the discharge ventilation. In case the fireplaces are omitted, a special vent flue, either of brick or of galvanized iron, should be provided. These should not be less than 8 by 12 inches for single wards, and the equivalent for each bed in a large ward. Each flue of this kind should have a loop of steam pipe for producing a draught. A loop of 1-inch pipe, 10 or 12 feet in height, is usually sufficient for this purpose.

Other rooms than wards are usually heated with direct radiators, the sizes of which may be computed in the same manner as for dwelling-houses.

Steam tables for the kitchen, sterilizers, and laundry machinery, require higher pressures than is necessary for heating.

In large plants the boilers are usually run at high pressure, and the pressure reduced for heating. A good arrangement for small plants is to provide sufficient boiler power for warming and ventilating purposes, and run at a pressure of 3 to 5 pounds. In addition to this, a small high-pressure boiler carrying 70 or 80 pounds should be furnished for laundry work and water heating.

Churches. Churches may be warmed by furnaces, by indirect steam, or by means of a fan. For small buildings the furnace is more commonly used. This apparatus is the simplest of all and is comparatively inexpensive. Heat may be generated quickly, and when the fires are no longer needed, they may be allowed to go out without danger of damage to any part of the system from freezing.

It is not usually necessary that the heating apparatus be large enough to warm the entire building at one time to 70 degrees with frequent change of air. If the building is thoroughly warmed before occupancy, either by rotation or by a slow inward movement of outside air, the chapel or Sunday-school room may be shut off until near the close of the service in the auditorium, when a portion of the warm air may be turned into it. When the service ends, the switch-damper is opened wide, and all the air is discharged into the Sunday-school room. The position of the warm-air registers will depend somewhat upon the construction of the building, but it is well to keep them near the outer walls and the colder parts of the room. Large inlet registers should be placed in the floor near the entrance doors, to stop cold draughts from blowing up the aisles when the doors are opened, and also to be used as foot-warmers.

Ceiling ventilators are generally provided, but should be no larger than is necessary to remove the products of combustion from the gaslights, etc. If too large, much of the warmest and purest air will escape through them. The main vent flues should be placed in or near the floor and should be connected with a vent shaft leading outboard. This flue should be provided with a small stove or flue heater made specially for this purpose. In cold weather the natural draught will be found sufficient in most cases.

The same general rules are to be followed in the case of indirect steam as have been described for furnace heating. The stacks are placed beneath the registers or flues, and mixing dampers provided. If there are large windows, flues should be arranged to open in the window-sills, so that a sheet of warm air may be delivered in front of the windows, to counteract the effects of cold down-draughts from the exposed glass. These flues may usually be made 3 or 4 inches in depth, and should extend the entire width of the window. Small rooms, such as vestibules, library, pastor's room, etc., are usually heated with direct radiators. Rooms which are used during the week are often connected with an independent heater so that they may be warmed without running the large boilers, as would otherwise be necessary.

When a fan is used, it is desirable, if possible, to deliver the air to the auditorium through a large number of small openings. This is often done by constructing a shallow box under each pew, running its entire length, and connecting it with the distributing ducts or a plenum space by means of a pipe from below. The air is delivered at a low velocity through a long slot, as shown in Fig. 174.

The warm-air flues in the window-sills should be retained, but may be made shallower, and the air forced in at a high velocity.

If the auditorium has a sloping floor, a plenum space may be provided between the upper or raised portion and the main floor. Sometimes a shallow basement 3 or 4 feet in height, with a cemented floor, and extending under the entire auditorium, is used as an air or plenum space.

If the basement is of good height and used for storage or other purposes, it is necessary to carry galvanized-iron ducts at the ceiling under the center of each double row of pews, and to connect with each pair by means of branch uptakes. The size of these should be equal to 3 or 4 square inches for each occupant.

Another method is to supply the air through a small register in the end of each pew. This simplifies the pew construction somewhat, but otherwise is not so satisfactory as the preceding method.

If the special pew construction is too expensive, or for any other reason cannot well be used, and the fan is to be retained, the greater part of the air is best introduced through wall registers placed about 8 feet above the floor, with exhaust openings at or near the floor. By this arrangement the air is thrown horizontally toward the center of the church, and much of it falls to the breathing level without rising to the upper part of the room.

Halls. The treatment of a large audience hall is similar to that of a church, the warming being usually done in one of the three ways already described. Where a fan is used, the air is commonly delivered through wall registers placed in part near the floor, and partly at a height of 7 or 8 feet above it. They should be made of ample size, so that there will be freedom from draughts. A part of the vents should be placed in the ceiling, and the remainder near the floor. All ceiling vents, in both halls and churches, should be provided with dampers having means for holding them in any desired position. If indirect gravity heaters are used, it will generally be necessary to place heating coils in the vent flues for use in mild weather; but if the fresh air is supplied by means of a fan, there will usually be pressure enough in the room to force the air out without the aid of other means. When the vent air-ways are restricted, or the air is impeded in any way, electric ventilating fans are often used. These give especially good results in warmer weather, when natural ventilation is sluggish. The temperature may be regulated either by using the double-duct system or by shutting off or turning on a greater or less number of sections in the main heater. After an audience hall is once warmed and filled with people, very little heat is required to keep it comfortable, even in the coldest weather.

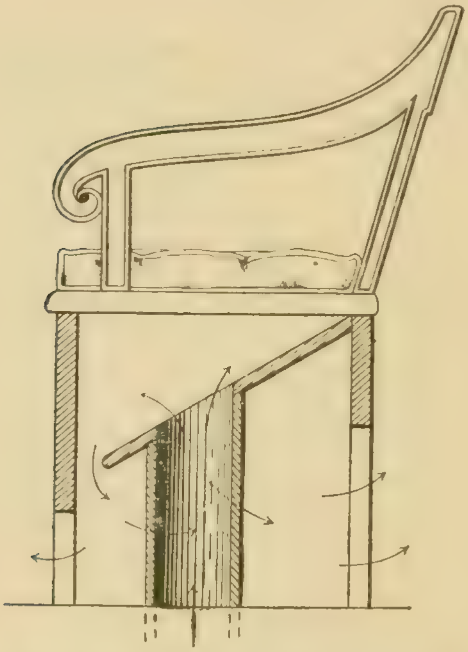


Fig. 174. An Approved Method of Delivering Warm Air to the Auditorium of a Church.

Theaters. In designing heating and ventilating systems for theaters, a wide experience and the greatest care are necessary to secure the best results. A theater consists of three parts: the body of the house, or auditorium; the stage and dressing-rooms, and the foyer, lobbies, corridors, stairways, and offices. Theaters are usually located in cities, and surrounded with other buildings on two or more sides, thus allowing no direct connection by windows with the external air; for this reason artificial means are necessary for providing suitable ventilation, and a forced circulation by means of a fan is the only satisfactory means of accomplishing this. It is usually advisable to create a slight excess of pressure in the auditorium, in order that all openings shall allow for the discharge rather than the inward leakage of air.

The general and most approved method of air-distribution is to force it into closed spaces beneath the auditorium and balcony floors, and allow it to discharge upward through small openings among the seats. One of the best methods is through chair-legs of special latticed design, which are placed over suitable openings in the floor; in this way the air is delivered to the room in small streams, at a low velocity, without draughts or currents. The discharge ventilation should be largely through ceiling vents, and this may be assisted if necessary by the use of ventilating fans. Vent openings should also be provided at the rear of the balconies, either in the wall or in the ceiling, and these should be connected with an exhaust fan either in the basement or in the attic, as is most convenient.

The close seating of the occupants produces a large amount of animal heat, which usually increases the temperature from 6 to 10 degrees, or even more; so that, in considering a theater once filled and thoroughly warmed, it becomes more of a question of cooling than one of warming to produce comfort.

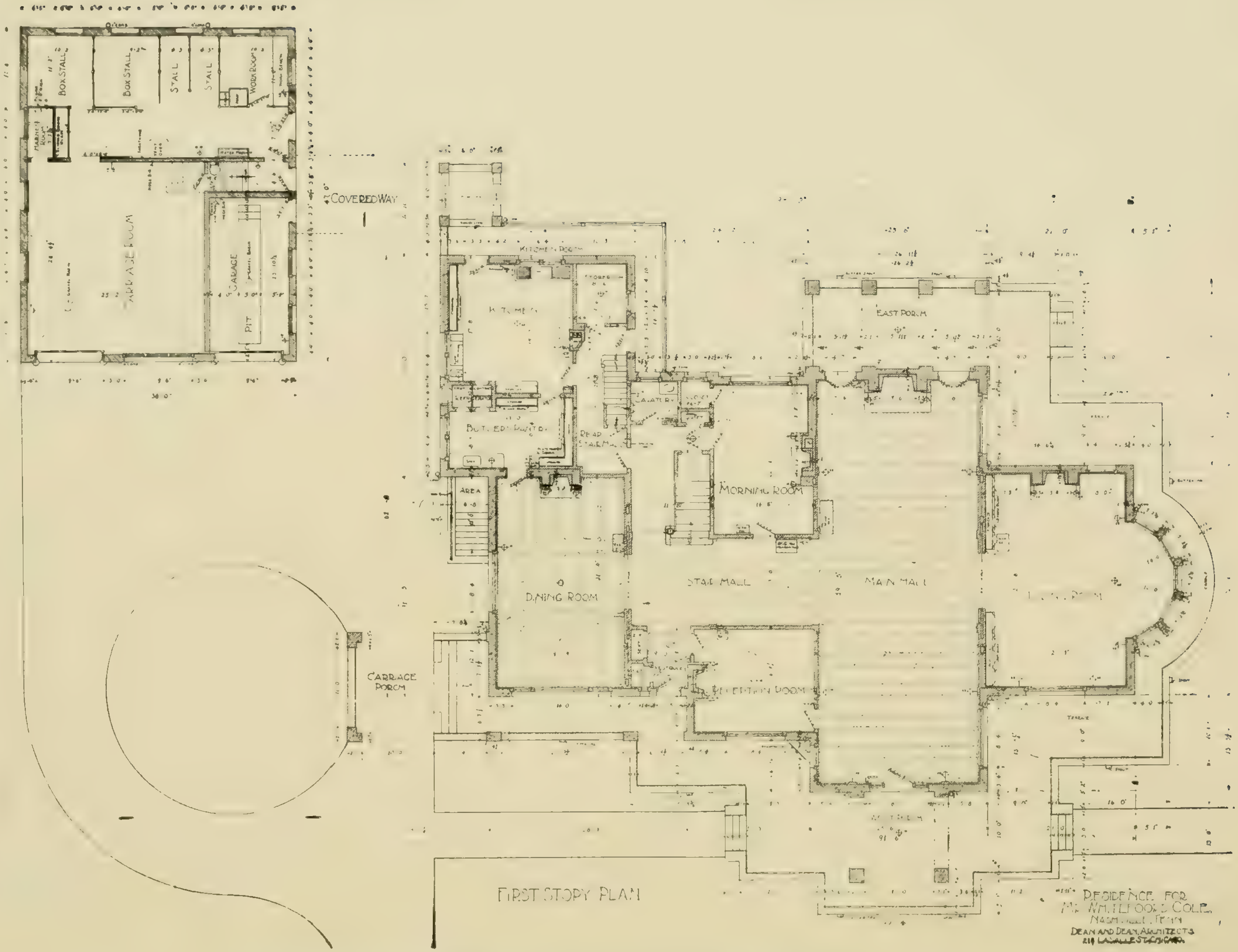
The dressing-rooms should be provided with a generous supply of fresh air, sufficient to change the entire contents once in 10 minutes at least, and should have discharge flues of sufficient size to carry away this amount of air at a velocity not exceeding 300 feet per minute, unless connected with an exhaust fan, in which case the velocity may be doubled. The foyer, corridors, dressing-rooms, etc., are generally heated by direct radiators, which may be concealed by ornamental screens if desired.

Office Buildings. This class of buildings may be satisfactorily warmed by direct steam, hot water, or, where ventilation is desired, by the fan system. Probably direct steam is used more frequently than any other system for this purpose. Vacuum systems are well adapted to the conditions usually found in this type of building, as most modern office buildings have their own light and power plants, and the exhaust steam can thus be utilized for heating purposes. The piping may be either single or double. If the former is used, it is better to carry a single main riser to the upper story, and run drops to the basement, as by this means the steam and water flow in the same direction, and much smaller pipes can be used than would be the case if risers were carried from the basement upward.

Special provision must be made for the expansion of the risers or drops in tall buildings. They are usually anchored at the center, and allowed to expand in both directions. The connections with the radiators must not be so rigid as to cause undue strains or to lift the radiators from the floor.

It is customary, in most cases, to make the connections with the end farthest from the riser; this gives a length of horizontal pipe which has a certain amount of spring, and will care for any vertical movement of the riser that is likely to occur. Forced hot-water circulation is often used in connection with exhaust steam. The water is warmed by the steam in large heaters similar to feed-water heaters and is circulated through the system by means of centrifugal pumps. This has the usual advantage of hot water over steam, inasmuch as the temperature of the radiators may be regulated to suit the conditions of outside temperature.

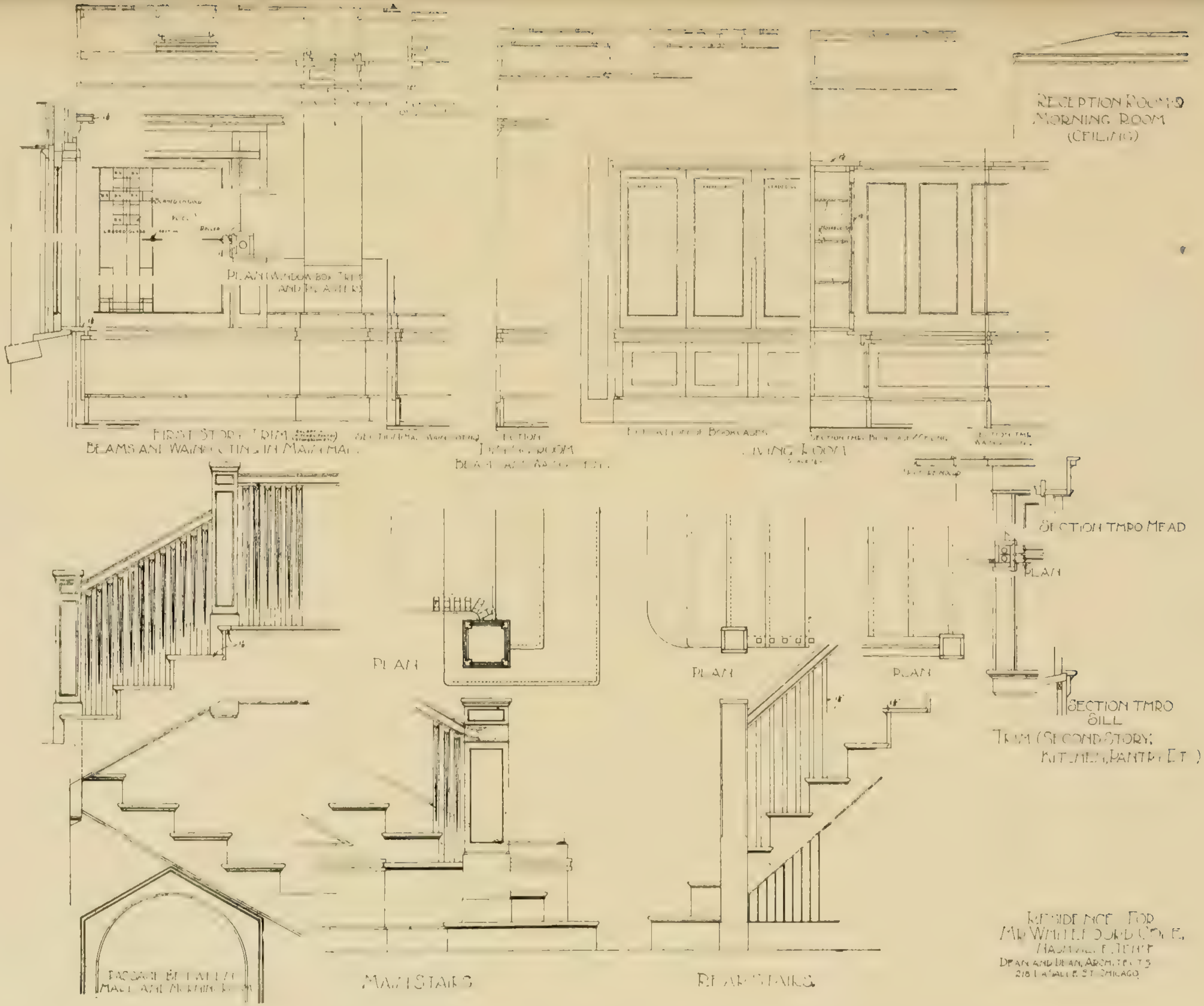
When a fan system is used the arrangement of the air-ways is usually somewhat different from any of those yet described. Owing to the great height of these buildings, and the large number of small rooms which they contain, it is impossible to carry up separate flues from the basement. One of the best arrangements is to construct false ceilings in the corridor-ways on each floor, thus forming air-ducts which may receive their supply through one or more large up-takes extending from the basement to the top of the building. These corridor air-ways may be tapped over the door of each room, the openings being provided with suitable regulating dampers for gauging the air-supply to each. Adjustable deflectors should be placed in the main air-shafts for proportioning the quantity to be delivered



FIRST-STORY PLAN OF RESIDENCE FOR MR. WHITEFOORD COLE, NASHVILLE, TENN.

Dean & Dean, Architects, Chicago, Ill.

For West and South Elevations, See Page 202. Interior Details Shown on Opposite Page.



INTERIOR DETAILS OF RESIDENCE FOR MR. WHITEFOORD COLE, NASHVILLE, TENN.

Dean & Dean, Architects, Chicago, Ill.

First-Story Plan Shown on Opposite Page. For Elevations, See Page 202.

to each floor. If both supply and discharge ventilation are to be provided, the fresh air may be carried in galvanized-iron ducts within the ceiling spaces, and the remainder used for conveying the exhausted air to uptakes leading to a discharge fan placed upon the roof of the building. In both of these cases, it is assumed that heat is supplied to the rooms by direct radiation, and that the air-supply is for ventilation only.

Apartment Houses. These are warmed by furnaces, direct steam, and hot water. Furnaces are more often used in the smaller houses, as they are cheaper to install, and require a less skilful attendant to operate them. Steam is probably used more than any other system in blocks of larger size. A well-designed single-pipe connection, with automatic air-valves dripped to the basement, is probably the most satisfactory in this class of work. People who are more or less unfamiliar with steam systems are apt to overlook one of the valves in shutting off or turning on steam; and where only one valve is used, the difficulty arising from this is avoided. Where pet-cock air-valves are used, they are often left open through carelessness; and the automatic valves, unless dripped, are likely to give more or less trouble.

Greenhouses and Conservatories. Buildings of this class are heated in some cases by steam and in others by hot water, some florists preferring one and some the other. Either system, when properly designed and constructed, should give satisfaction, although hot water has its usual advantage of a variable temperature. The methods of piping are, in a general way, like those already described, and the pipes may be located to run underneath the beds of growing plants or above, as bottom or top heat is desired. The main is generally run near the upper part of the greenhouse and to the farthest extremity, in one or more branches, with a pitch upward from the heater for hot water and with a pitch downward for steam. The principal radiating surface is made of parallel lines of 1½ inch or larger pipe, placed under the benches and supplied by the return current. Figs. 175, 176, and 177 show a common method of running the piping in greenhouse work. Fig. 175 shows a plan and elevation of the building with its lines of pipe; and Figs. 176 and 177 give details of the pipe connections of the outer and inner groups of pipes respectively.

Any system of piping which gives free circulation and which is adapted to the local conditions, should give satisfactory results. The radiating surface may be computed from the rules already given. As the average greenhouse is composed almost entirely of glass, we may for purposes of calculation consider it such; and if we divide the total exposed surface by 4, we shall get practically the same result as if we assumed a heat loss of 85 B. T. U. per square foot of surface per hour, and an efficiency of 330 B. T. U. for the heating

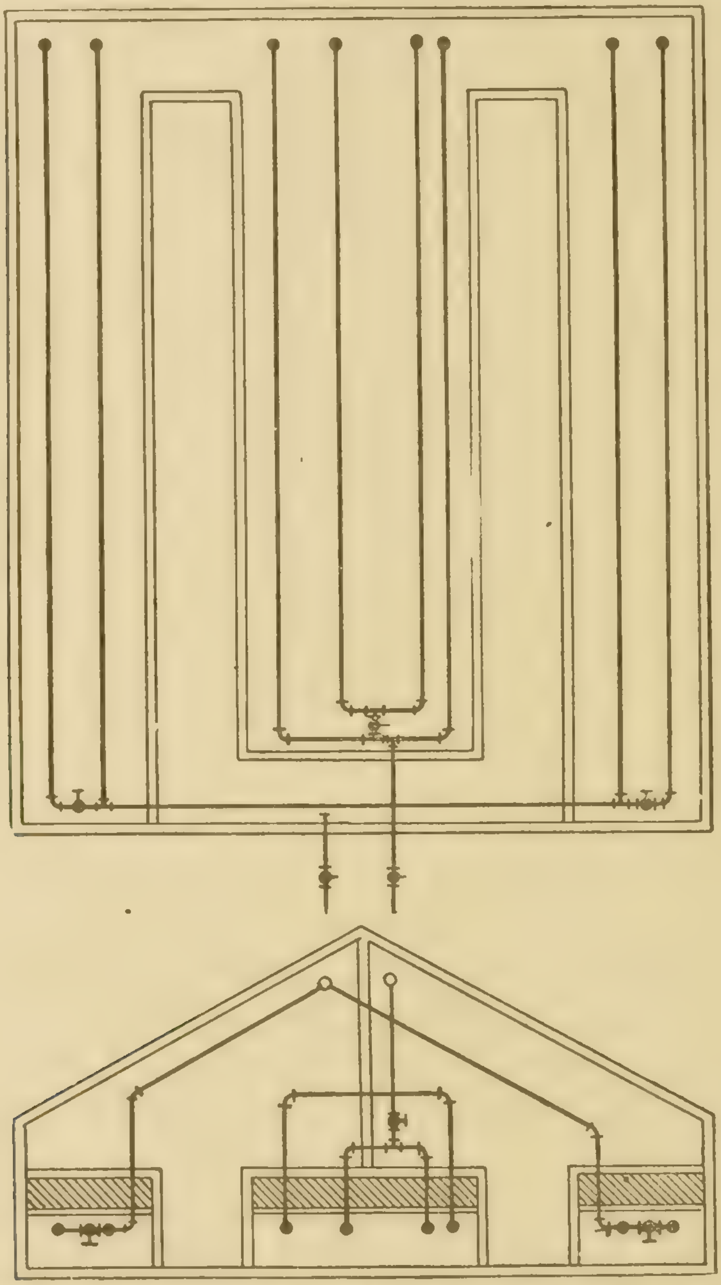


Fig. 175. Plan and Elevation Showing One Method of Running Piping in a Greenhouse

coils; so that we may say, in general, that the square feet of radiating surface required equals the total exposed surface, divided by 4 for steam coils, and by 2.5 for hot-water. These results should be increased from 10 to 20 per cent for exposed locations.

CARE AND MANAGEMENT

The care of furnaces, hot-water heaters, and steam boilers has been discussed in connection with the design of these different systems of heating, and need not be repeated. The management of the heating and ventilating systems in large school buildings is a matter of much importance, especially in those using a fan system. To obtain the best results, as much depends upon the skill of the operating engineer as upon that of the designer.

Beginning in the boiler-room, he should exercise special care in the management of his fires, and the instruction given in "Boiler Accessories" should be carefully followed; all flues and smoke passages should be kept clear and free from accumulations of soot and ashes by means of a brush or steam jet. Pumps and engine should be kept clean and in perfect adjustment, and extra care should be taken when they are in rooms through which the air-supply is drawn, or the odor of oil will be carried to the rooms. All steam traps should be examined at regular intervals to see that they are in working order; and upon any sign of trouble, they should be taken apart and carefully cleaned.

The air-valves on all direct and indirect radiators should be inspected often; and upon the failure of any room to heat properly, the air-valve should first be looked to as a probable cause of the difficulty. Adjusting dampers should be placed in the base of each flue, so that the flow to each room may be regulated independently. In starting up a new plant, the system should be put in proper balance by a suitable adjustment of these dampers; and, when once adjusted, they should be marked, and left in these positions. The temperature of the rooms should never be regulated by closing the inlet registers. These should never be touched unless the room is to be unused for a day or more.

In designing a fan system, provision should be made for *air-rotation*; that is, the arrangement should be such that the same air may be taken from the building and passed through the fan and

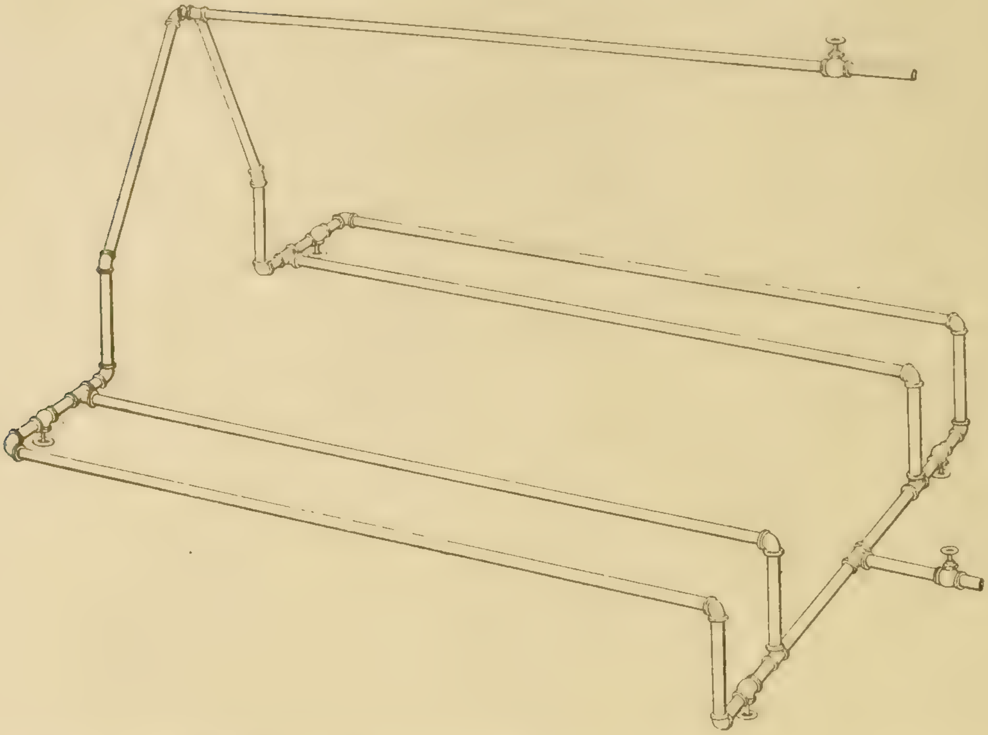


Fig. 176. Connections of Outer Groups of Pipes of Greenhouse Shown in Fig. 175.

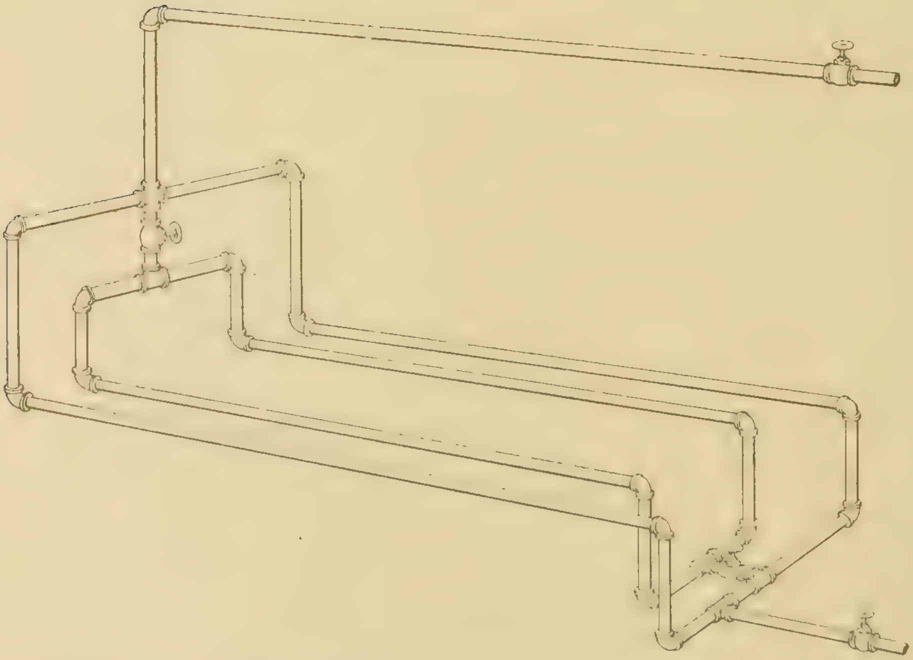
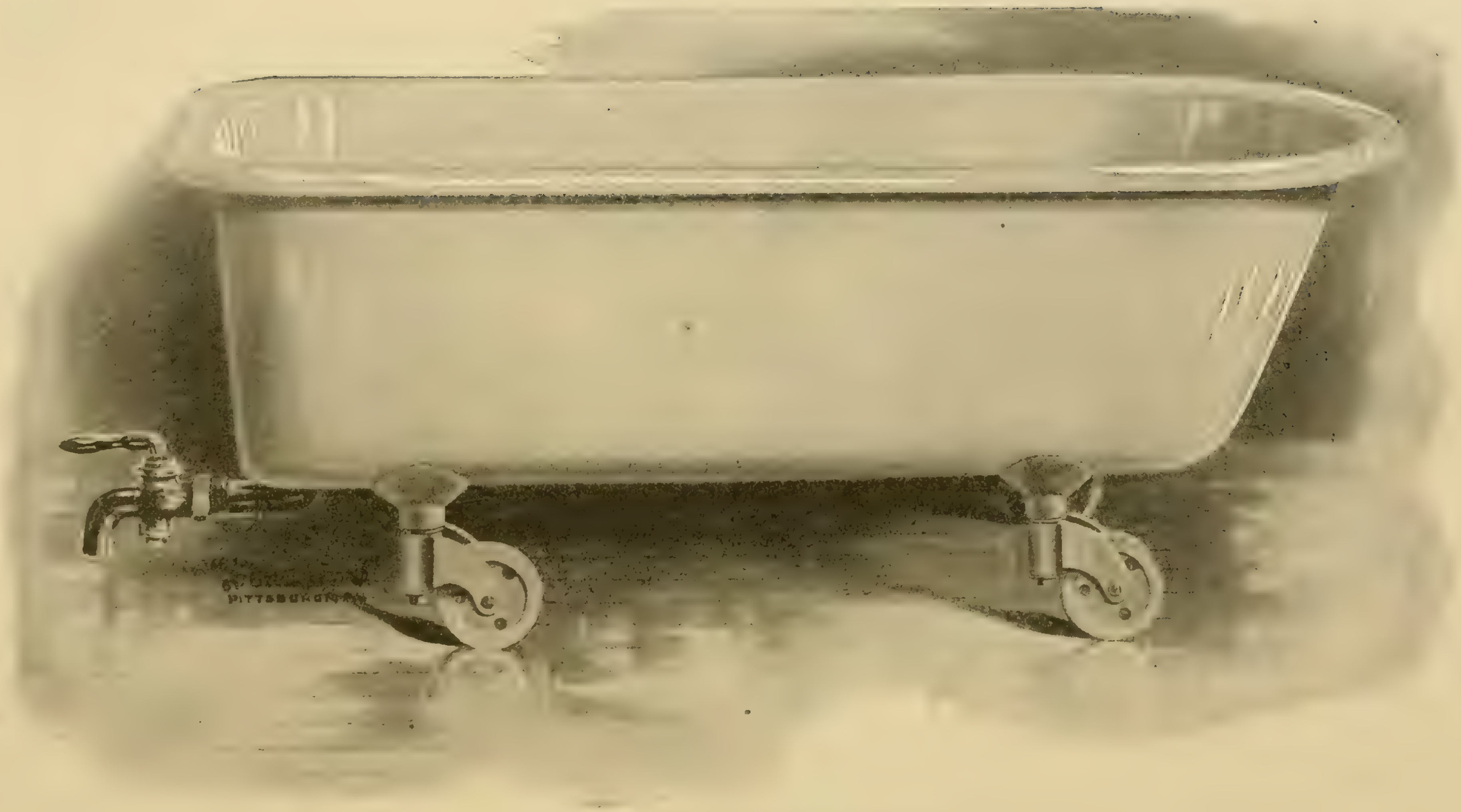


Fig. 177. Connections of Inner Groups of Pipes of Greenhouse Shown in Fig. 175.

heater continuously. This is usually accomplished by closing the main vent flues and the cold-air inlet to the building, then opening the class-room doors into the corridor-ways, and drawing the air down the stair-wells to the basement and into the space back of the main heater through doors provided for this purpose. In warming up a building in the morning, this should always be done until about fifteen minutes before school opens. The vent flues should then be opened, doors into corridors closed, cold-air inlets opened wide, and the full volume of fresh air taken from out of doors.

At night time the dampers in the main vents should be closed, to prevent the warm air contained in the building from escaping. The fresh air should be delivered to the rooms at a temperature of from 70 to 75 degrees; and this temperature must be obtained by proper use of the shut-off valves, thus running a greater or less number of sections on the main heater. A little experience will show the engineer how many sections to carry for different degrees of outside temperature. A dial thermometer should be placed in the main warm-air duct near the fan, so that the temperature of the air delivered to the rooms can be easily noted.

The exhaust steam from the engine and pumps should be turned into the main heater; this will supply a greater number of sections in mild weather than in cold, owing to the less rapid condensation.



Standard Bath Tub for Hospital Use.

PLUMBING

PART I

Plumbing occupies an important position among the trades as an application of Sanitary Science.

Sanitary science is defined by an eminent authority* as "that body of hygienic knowledge, which, having been sufficiently and critically examined, has been found so far as tested to be invariably true. Its phenomena are natural phenomena; its laws are natural laws; its principles are scientific principles."

The same authority defines the sanitary arts as "those methods and processes by which the applications of the principles of sanitary science are effected," and would include plumbing with other practical arts of construction involved in sanitary engineering and architecture.

Having thus noted the position occupied in this broad field by the matters under consideration, we may define plumbing as *the art of placing in buildings the pipes and other apparatus used for introducing the water supply and removing the foul wastes.*

Historically, the plumber is primarily one who works in lead; but this definition would be a misnomer applied to the handicraftsman of to-day. While in time past, and even within the memory and practice of men now working at the trade, it suited the occupation designated as *plumbing*, the term "plumber" survives the transition from lead to iron more by reason of established usage than from its fitness to indicate the workman of the present.

Two score of years ago, traps and soil, waste, and supply pipes were in many localities almost wholly of lead; and much of the larger pipe was hand-made. Lead was then everywhere more frequently used for all these purposes than it is anywhere in the country now. To-day, first-class plumbing is possible in any type of building without employing a vestige of lead, and that, too, with fixtures and fittings regularly on the market. Lead, however, is still used to a marked extent in plumbing, principally for traps, pipe connections, calked joints, water-service pipes, tank linings, flashings, etc. Its retention for these secondary purposes is due generally to superior fitness; yet in some instances it is because of the style of connection provided on certain fixtures, or for other reasons independent of the merits of the metal. On the whole, its loss of prestige has been slow and impartial. Indeed, those manually skilled in the manipulation of lead have often opposed the adoption of other materials sufficiently to retard substitution of the better.

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* *The Principles of Sanitary Science*, by Wm. T. Sedgwick.

Lead has unequaled merit for plumbers' use in specific instances; and if the trade has suffered by injudicious substitution of other material during its rapid evolution in recent years, time will adjust the error as the fitness of lead becomes apparent. For service lines in the ground, no other material lasts longer or gives more satisfaction than lead, provided the use of lead is safe with the particular water which flows through it. For cold-water lines inside buildings, it answers well. Wood tanks properly lined with lead are, in many cases, the best for indoor storage.

Lead pipe is not self-supporting in any position, in the sense that iron or brass may be considered so; and the providing of reasonably permanent support for lead work is an expensive item. Lead pipe costs more than iron or brass, in every case; and the cost increases proportionally with the extra weight necessary for all but very light pressures; while ordinary merchant's iron pipe, or seamless brass pipe of iron-pipe size, will withstand the pressure of any municipal or private supply in America.

Lead does not serve well for hot water. The contraction while cooling appears not to equal the expansion from heating; hence the pipe deteriorates at the hottest points, usually showing weakness first near the reservoir in the kitchen, especially at bends, and finally crystallizing beyond repair at those points. So much trouble has been experienced with stove and range connections of lead, that lead pipe for this purpose has been entirely abandoned. The wish to install something better suited than lead for hot-water service, is in large measure responsible for the general adoption of other material. Hot and cold supply lines that are dissimilar in material, in diameter, in joints, and in fastenings, are so unsymmetrical and out of harmony in every way that no mechanic is willing to install them for a slight real or fancied betterment.

With reference to the action of frost, lead pipe has an advantage in that the diametrical expansion of the water when freezing does not burst the pipe at the point frozen, unless it has been repeatedly swelled from the same cause. Lateral extension of the core of ice in the portion frozen, crowds the water which it cannot compress; and, as the ice is frozen to the wall of the pipe, the weakest place ruptures. Sometimes a faucet ball will be driven in, and occasionally a coupling collar will be stripped of its threads; but usually room is made for the extra volume of the water by the pipe swelling to an egg-shape and bursting at one point. Such a break can be repaired by wiping a single patch or joint on the original pipe.

Frost breaks in lead pipe nearly always occur on the house side of the point frozen, because the water in the street end is easily driven toward the main. Air-chambers on the house service would often obviate the bursting of lead pipe; but where the type of faucets or a limited pressure does not require their use in order to prevent reaction, plumbers frequently omit them, under the impression that air-chambers can serve no other good purpose.

With iron pipe, frost breaks are more serious. Diametrical expansion splits the pipe at the point frozen every time freezing occurs; and lateral extension of the ice staves in the faucet stems, etc., quite as frequently as would happen with lead pipe under the same conditions. Of late years, the improvement in types of buildings, more careful provision against frost on the part of plumbers, and the vigilance of the Weather Bureau in giving warning of approaching cold snaps, have made insignificant the amount of damage by frost in both kinds of pipe.

Lead pipe, as a rule, requires less trench work on ground lines than iron pipe, because drilling, even if very poorly aligned, will often suffice to get the pipe in place. There are numerous instances, however, where longer stretches of iron pipe have been placed in drilled holes than would be practicable with lead at the same excavating cost. It is well to remember that any small line of house service in the ground should be placed deeper, so far as immunity from frost alone is concerned, than is necessary for the protection of large pipes in the same locality, because the volume of contents in house pipes is small, the wall surface of the pipe relatively large, and the flow of the water not so regularly maintained.

The action of natural waters on lead has been a matter of wide discussion by able men. The subject of possible contamination of water supply through the agency of lead conduits, is too broad, however, for full consideration here, and will therefore be but briefly touched upon. This trait of lead has been voiced against its use, with more or less effect; but known cases of poisoning from this source have been exceedingly rare. Galvanized-iron pipe charges the water with salts of zinc when the water contains certain impurities; and most other kinds of pipe are also more or less open to objection at times by reason of their injurious effect on the water, the staining of fixtures, etc. Some of the salts of lead formed by the agency of water conveyed through lead supply pipe, are protective. Others, without doubt—fortunately of rare occurrence is actual practice—are corrosive. Sulphate or phosphate of lime, in solution, will part with its acid in passing through lead pipe, the acid combining with a new base (lead) and forming sulphate or phosphate of lead as the case may be. Chloride, sulphate, nitrate, borate, and other compounds of lead, may be similarly formed. These incrust the pipe; and such of them as are practically insoluble in water protect the lead from further attack, thus preserving the quality of the water. Carbonate, sulphate, and phosphate of lead, which doubtless form most frequently in lead water pipes, belong to the protective class. Of course, not all the compounds mentioned are encountered in any one source of supply. Chemical compounds designed to produce an insoluble incrustation have sometimes been purposely placed in solution, and allowed to stand in systems of lead supply pipe where it was known that the water to be commonly used would otherwise be dangerously corrosive. In view of the possibility of such precautionary measures, the deleterious effect of lead on many water supplies, and the consequent menace to health if lead were used indiscriminately, could hardly alone to any appreciable extent result in the substitution of pipe of other material.

Lead has been thus dwelt upon at the outset, because the industry of plumbing itself derived its name from this metal (*Plumbum*, Latin for "lead"). A discussion sufficient to define broadly the present and past status of the metal in the plumbing business, is certainly apropos in this connection. To many persons, the term "Plumbing" suggests lead and lead work generally, without regard to its distinctive forms, some of which are quite foreign to the ordinary trade meaning. To those acquainted with the building practices of Europe, visions of lead-covered roofs and spires, rainwater heads, etc., in addition to manifold other uses of the metal not common in America, may come to view in the mind's eye when "plumbing" is mentioned. To American plumbers of the past generation, "plumbing" suggested stacks of hand-made lead soil and waste pipe; hand-made lead traps; lead "safe" pans cumbersomely boxed-in under fixtures; ridiculously small lead ventilation pipes; lead drip-trays; lead supply pipes (sometimes also hand-made); all "wiped" joints and seams; and blocks, flanges, braces, boards, and boxes galore, jutting out in profusion, for supports, covering, etc.

In reality, we in America have now but little of what the name "plumbing" would lead the uninitiated to expect. Stacks of plain or galvanized wrought-iron pipe, or of plain, tarred, or galvanized cast-iron pipe, of weight to suit the height of building and to serve as main soil, waste, and ventilation pipes, with sundry lead bends and ends for fixture connections—these, with galvanized wrought-iron or brass pipes for supply, constitute the "roughing-in" stage of a job of plumbing; while painted or bronzed main lines exposed to view, galvanized-iron and nickel-plated brass pipe, with fixtures, partitions, etc., make up a view of the finished work, conveying little idea of the functions and importance of the unseen portions. Finished work in an unpretentious dwelling or storehouse, when properly charted, is fairly easy for even the house-man to understand. In large apartment and office buildings, department stores, etc., however, the plumbing, ventilating, gasfitting, heating, and automatic sprinkler pipes and electric conduits, make, in any but the finished state, a maze of pipe beyond the understanding of any except engineers well versed in those lines of work. In the completed work, the details are concealed. The toilet rooms present an orderly perspective of closets, lavatories, or other fixtures, as the case may be, with simple connections according with the customary finish, kind, or purpose of the pipe.

This apparent harmony, proportion, and simplicity in the result, coupled with a memory of sundry glimpses of a confusion of pipes in the rough state, has, it is to be regretted, propagated in many minds, a sense of false security regarding plumbing, based on the assumption of the plumber's evident ability to produce order and perfect service out of what in the "roughing-in" stage looked chaotic to a hopeless degree. The bulk of plumbing work, however, is not of the "skyscraper" class, nor is it handled by the same type of skill and superintendence. Any feeling of confidence or sense of security on the part of the public, is treacherous if based on the assumption that only by a degree of skill in direct proportion to the size of the job can satisfactory plumbing service be provided in residential and other small buildings. There is evidence of a somewhat indifferent state of the public mind regarding the plumber and his work, induced by the reasons stated and also by lack of due consideration and appreciation of conditions wrought by progress in other trades.

Plumbing, in its advancement, is merely keeping pace with the allied lines on which it is dependent. Their progress has created new conditions to be met; and as the future plumber will hail from the ranks of the populace, the light in which the public regards the plumber and the importance of his trade will have no uncertain bearing on the character and earnestness of those who take up the calling. The rank and file of apprentices have already too long been attracted merely on the score of a promising means of livelihood. There is ample reason to begin a plumbing career with all the pride felt by followers of any other vocation. It is altogether improbable that any individual will be found with so much education or such promising ability as to give rise to just grounds of fear that plumbing will not offer him sufficient scope to acquit himself with dignity.

The advent of tall buildings, the general increase in the height and other proportions of buildings in cities, and the changes in material and in design of fixtures, together with the abnormal demand resulting from the decreased cost, natural growth, and gradual awakening through education to the value of sanitary conveniences, have brought about a condition of affairs which the old-line plumbers were incapable of coping with, and which the old apprenticeship system was inadequate to provide men capable of dealing with in a creditable manner. The plumbing of one large building involves as much work as hundreds of the average small jobs put together. The handling of such work under the conditions that have prevailed, has developed a deplorable state of so-called "specialism." Men engaged in "roughing-in" a large job are likely to tell you with entire truthfulness that they have no idea what types of closets or other fixtures are to be used; that they know nothing of the principles or merits of plumbing fixtures, and do not need to; that they never connected a fixture in their whole career; that the finishers do that kind of work. By further inquiry one would find the "finishers" utterly at sea in the work of "roughing-in," and accordingly ignorant of the whys and wherefores that govern the success of a job as a unit. These men, called "plumbers," are exceedingly skilful and rapid within their limitations; but it is easy to infer the fate of a job intrusted to such hands alone, and in practice it has been proven that others of metropolitan practice, and merely lacking in variety of experience, were not capable of creditable results on general residence work of the ordinary class.

When the largest jobs were completed in a comparatively short time, and when much of the training which went to make up the plumber's accomplishments was credited to the manual practice necessary to master the working of lead and solder, a period of service in shop and job practice, coupled with oral instructions from the journeyman, served fairly well to make a plumber out of raw material within the period allotted by the American abridgment of the apprenticeship term. On the work of to-day, however, there would be great chances of an apprentice serving such a term without seeing anything of more than from two to five jobs. He would be lucky if it fell to his lot to get even a little experience in each of the natural divisions of those jobs; and again fortunate if those jobs happened not to have the same general layout or to employ identically the same make of fixtures, for there are many shops which seem to have the faculty of securing work from certain particular sources, and which are equally likely for one reason or another to be recommending and using, where possible, one particular make of goods to the exclusion of other kinds just as good or better. These and kindred features now met with on every hand in practice, are stumbling-blocks—prohibitive, in fact, of anyone learning the plumbing trade within any period of time that can sensibly be prescribed for the acquiring of a trade or profession.

For more than a decade, the often-avowed reluctance of journeymen to teach apprentices has been held responsible for the trend of these affairs affecting the practice of the industry; but in the light of what has been said, it is easy to determine what it was that really introduced the Plumbing Correspondence School and Plumbing Trade Classes. It was *necessity*. Trade journals have done and are still doing good work in this line; but their best efforts, added to the opportunities of practice, were insufficient. There was no other satisfactory solution than the Correspondence School—no other route to the acquisition of principles and acquaintanceship with the accumulated information as to the relative merit or fitness of certain materials, designs, systems, etc., and as to the conditions under which this or that would serve well, while it might act just the reverse under other circumstances.

Under the present *régime*, it is not only apprentices and those who intend becoming such, but journeymen as well, that need to seek aid in the schools. The citizen at large, also, serves his own interest in informing himself in a general way at the same fountain, so as to be able to discriminate for himself in matters pertaining to plumbing. Furthermore, any real plumber would prefer that his customer should be familiar with the work in hand. Fewer misunderstandings occur when such is the case, and there is a keener appreciation of good work on one hand and a corresponding effort to merit approval on the other. There is, too, in favor of the plumber, when the customer is informed, an absence of those niggardly tactics of trying to secure much for little, of sacrificing quality and future satisfaction by reducing first cost below the safe limit. The well-informed customer never makes you feel that all plumbing is alike to him and a necessary evil to be paid for at rates far in excess of its value.

With the foregoing introduction in mind let us look further into the subject and see what "Plumbing" really is. Whether we are actual or self-nominated apprentices, journeymen, masters, or the prospective customer himself, a view of the matter will be beneficial, if only in the sense of refreshing memory.

There was a time when sanitary conveniences, crude in comparison with the present, were considered mere luxuries. Under the present views of life and the conditions of living, we may with greater propriety consider these erstwhile luxuries as actual necessities, though they are often luxurious to a degree that dwarfs into insignificance other appointments which even then were granted to be essentials. Plumbing is, therefore, neither in fact nor in opinion, a matter of simple luxury for the rich and delicate, but is, rather, an important subject of deep salutary interest on the one hand and of business acumen on the other—a matter of essentials deeply affecting the best interests of our own health and that of our neighbors, with which mere sentiment has no ground for association. The time when it was thought sufficient to fan out the mosquitoes in summer and break the ice in winter at the family rain barrel in order to wash our faces and hands, has passed. A dwelling job may now embrace almost the entire range of plumbing fixtures. There is therefore no better example from which to build a word-picture of Plumbing.

PLUMBING FIXTURES

Bathtubs. Bathtubs are a prime factor in plumbing. They are of various types:—(1) Wooden cases, with sheet-metal lining, usually copper, on the order shown in Fig. 1; (2) all copper, and steel-clad, suitably mounted, as shown in Fig. 2; (3) cast iron, enameled, with a vitreous glaze fused on the iron, as in Figs. 4 and 5; (4) solid porcelain, potter's clay properly fired, with vitreous glaze fired on, as in Fig. 3; and (5) marble, variegated or otherwise, cut from the solid block. Their cost ranges in the order mentioned.

The relative merit of the different materials and types is not so easily designated. Porcelain and marble baths are large, very heavy, and imposing-looking; and therefore are often selected on the score of massiveness, with a view to harmonizing with the dimensions and finish of the house. One would suppose the mass of material in such baths would have the effect of cooling the water to an annoying extent; but careful tests have revealed no appreciable difference in the effect of thin as compared with thick bathtubs on the warmth of water, and but little in their pleasantness of touch to the person. The bath of most pleasant touch was that of indurated wood fiber, which, however, had but little commercial success, on account of its lack of stability.

Most baths are made in from two to five regular sizes, ranging from 4 to 6 feet in extreme length. The general shapes are the *French* (Fig. 3); the *Modified French* (Fig. 4); and the *Roman* (Fig. 5). The various French patterns have the waste and supply fittings at the foot, which is modified in form to accommodate them. The waste water travels the length of the tub to reach the outlet, and generally leaves scum and sediment on the interior while emptying. Baths of the French type are suited to corner positions, or to positions in which one side runs along the wall; but the ideal position for a bathtub, in the interest of cleanliness, is with the foot end to the wall,

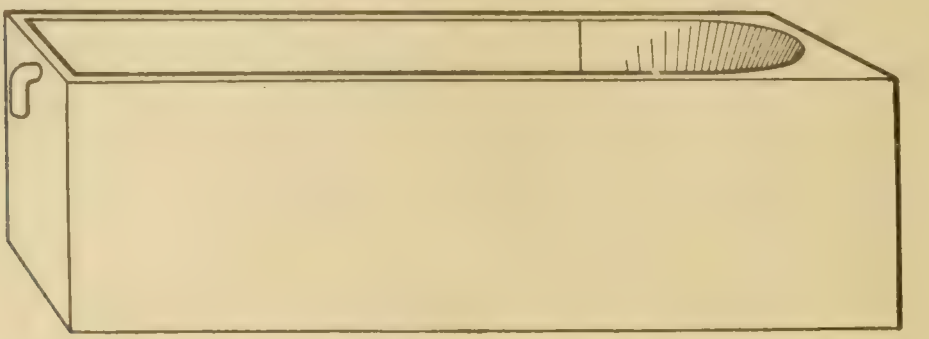


Fig. 1. Wooden Case Bathtub, with Sheet-Metal Lining.

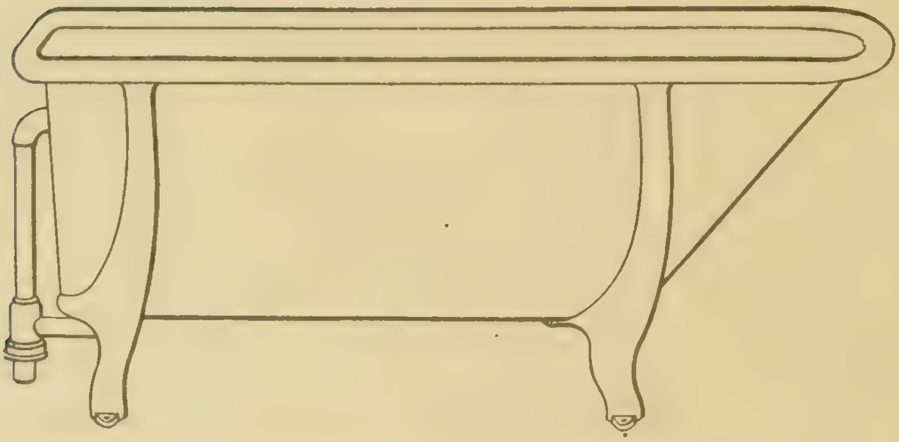


Fig. 2. All Copper, Steel-Clad Bathtub.

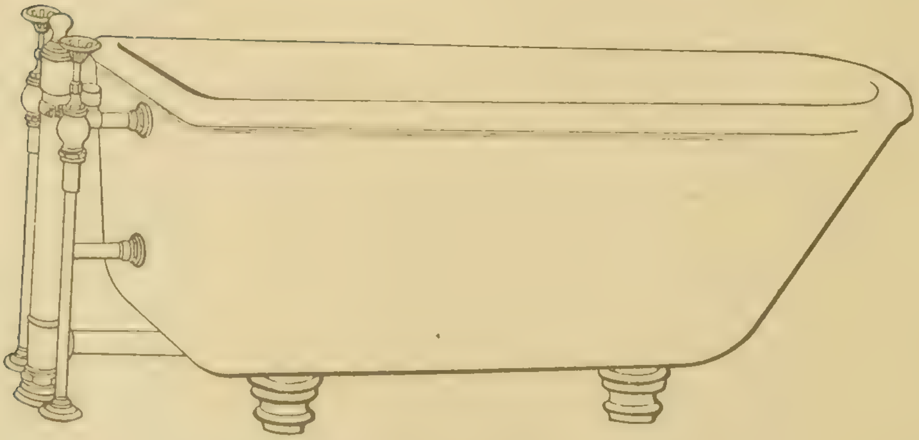
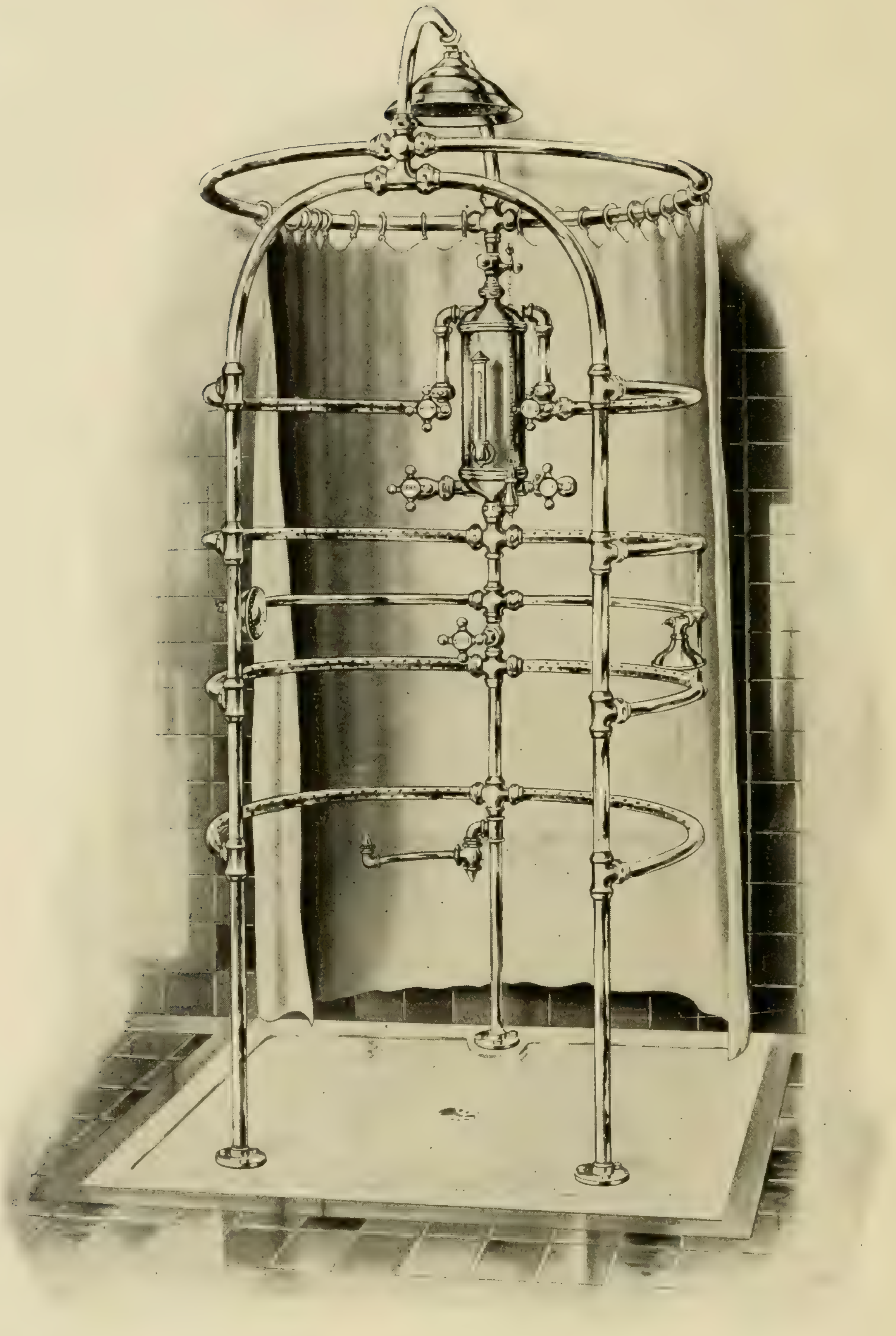
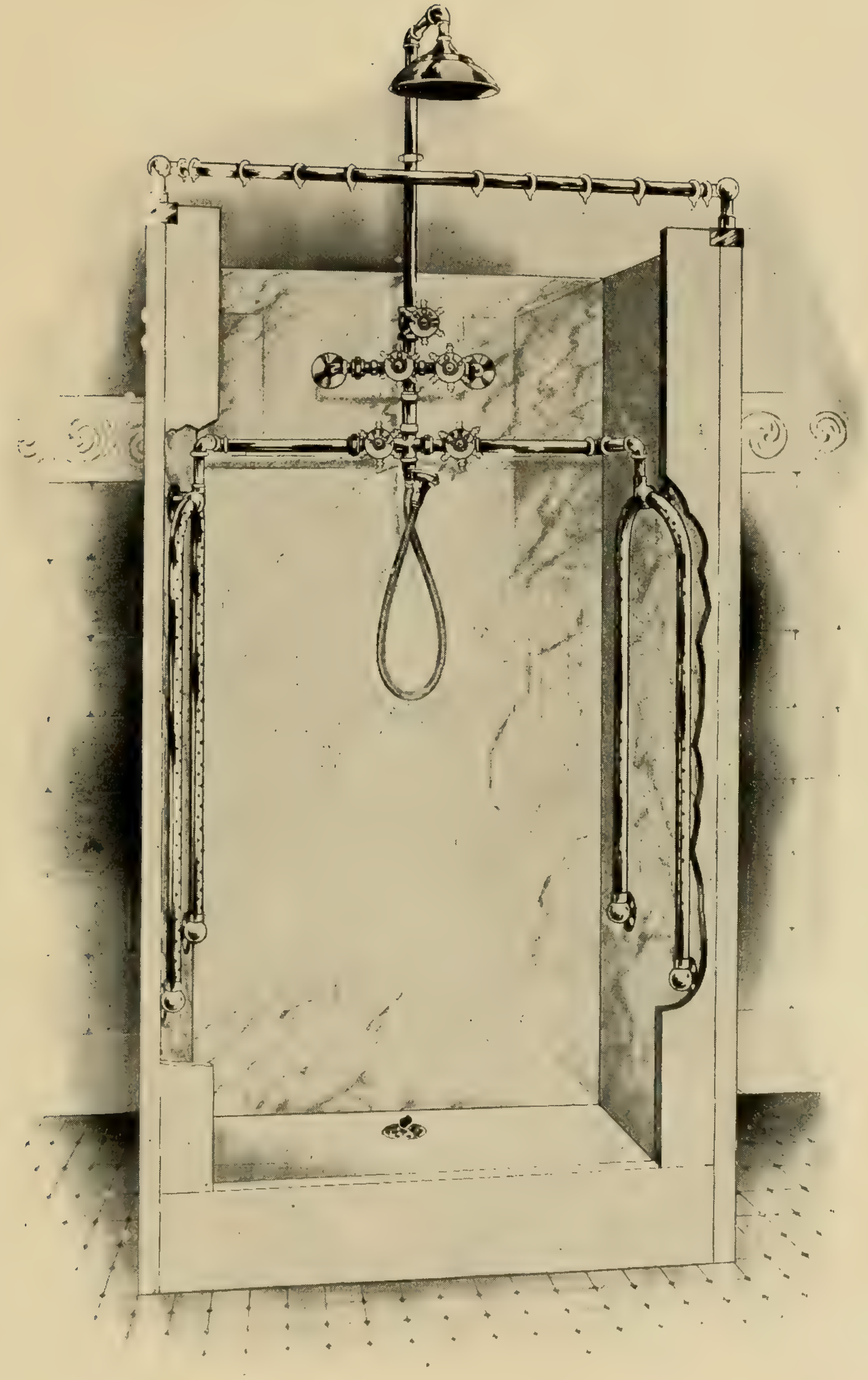


Fig. 3. Solid Porcelain Bathtub, French Type.



COMBINED NEEDLE AND SHOWER BATH ARRANGED FOR HOT AND COLD WATER.
The Federal Company.



NICKEL PLATED BRASS SHOWER BATH.

The Federal Company.

thus permitting entrance from either side. A medium size is best suited to the usual provision for supplying hot water for bath purposes; and is also preferred by many because the feet reach the foot, enabling a person, when submerging the body, to keep his head out of water, with his shoulder resting on the slant at the head of the tub. Where the house supply is pumped by hand, the medium size of any kind of bath is advisable.

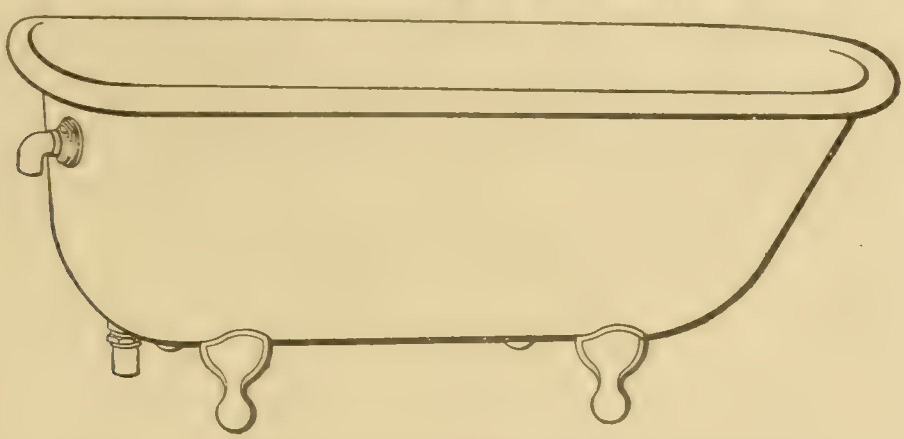


Fig. 4. Enameled Cast-Iron Bathtub, Modified French Type.

The rims of baths vary from 1½ to 5 inches in width. The larger rims are easy on the person in getting in and out of the bath, and are often used in lieu of a bath seat. In iron baths with rims large enough, the fittings are generally passed through the rim, as illustrated in Fig. 6, thus giving them additional stability and making the stated fixture length include the whole space necessary for its installation. This style of bath fitting is shown in Fig. 7.

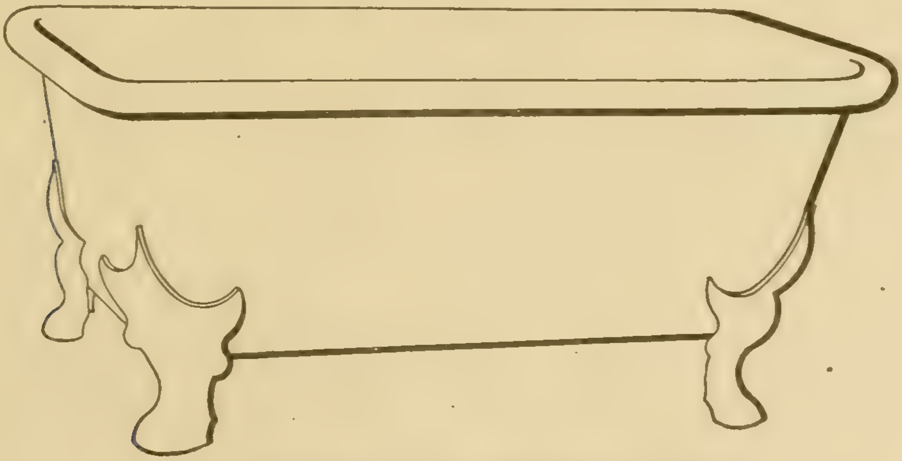


Fig. 5. Enameled Cast-Iron Bathtub, Roman Type.

Nominal sizes of baths now include the whole length of the fixture proper. Formerly many awkward mistakes resulted from lack of uniformity, one not always knowing whether to consider the nominal size as inside measurement only or including twice the rim width. In cast tubs, actual measures vary slightly from the nominal, because of the furnace effect when heating to enamel. The variation, however, is not sufficient to be considered in noting the space required, or to require any advance in roughing-in measurements.

Roman baths have ends alike, with the fittings at the center of one side, as illustrated in Fig. 8, and the waste outlet at the center of width and length. In general, they empty with better effect, and may be placed in either right or left corner or free of all the walls; but the best position, everything considered, is with the fitting side near the wall, and not against either end of the room.

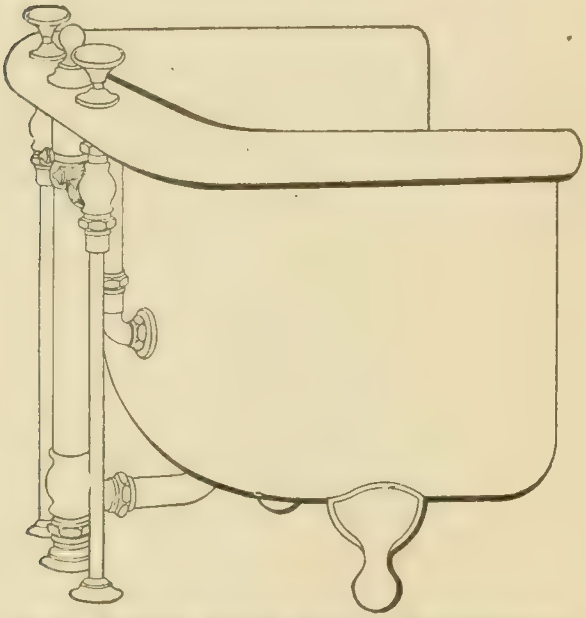


Fig. 6. Fittings Passed through Rim of Enameled-Iron Bathtub, to Give Additional Stability.

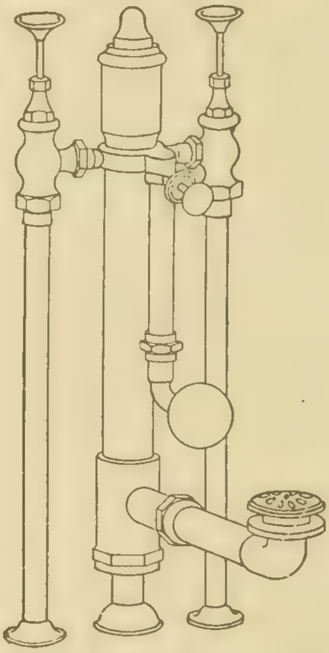


Fig. 7. Style of Bath Fitting Intended to Pass through Rim of Tub.

Any finish for iron bathtubs, other than plain paint, should be put on at the factory; iron surfaces cannot be ground and the successive coats of paint dried on in place, properly or cheaply.

Waste fittings and the outlets of baths have always been made too small. Slow emptying takes valuable time, and results in the adherence of scum, which necessitates careful cleansing of the bath before it is used again.

The fittings of baths are not interchangeable unless the obliqueness of the tub walls and the depth and drilling agree. The styles of fittings are universally applicable, except that double bath-cocks

(Fig. 9) are never placed on Roman baths. All double cocks are provided with detachable coupling and sprinkler, which, fitted to hose, provide a means of spraying the body. Independent spray, needle, shampoo, and overhead shower fixtures, simple and in combination, with or without curtains, are made for use with the various tubs, the tub serving as a receptor for the falling water.

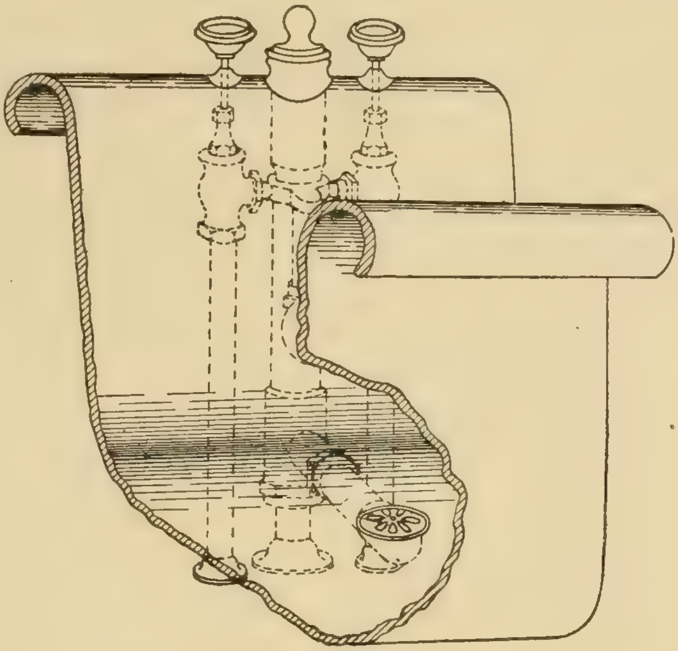


Fig. 8. Showing Central Location of Fittings and Waste Outlet in Roman Bathtub.

The cheapest serviceable bath fittings are a Double Cock and Connected Waste and Overflow. These are shown in Fig. 10. Bell Supply and Waste fittings, a special type of which is shown in Fig. 11, are singularly popular, the water being retained by a ring valve attached at the bottom of the overflow pipe, and operated by means of a knob projecting above and through the top of the waste standpipe. This takes the place of the ordinary plug and chain used with the simple overflow. The supplies are made and fitted in combination with the waste arrangement, with the valve handles projecting above the rim of the bath, the two supplies being delivered into a common yoke-piece, where they mix and flow through a common passage to the bell-piece fitted through the vertical wall near the bottom of the bath. With the usual slotted-bell delivery, these fittings are a nuisance in one respect. Water cannot be drawn into a vessel through the bell for any ulterior purpose; and as no vessel of considerable capacity can be filled at the lavatory faucets, or at a sitz or a foot bath, the sink faucets are the only resort unless a

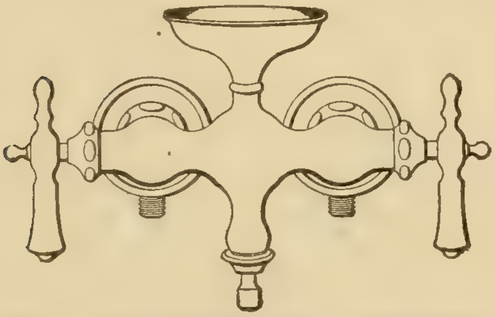


Fig. 9. Double Bath-Cock. Never Used on Roman Bathtubs.

slop sink is available. Nozzle-delivery bells, which afford some relief in this respect, are made; and hand sprays used in conjunction with them avoid the expense of special shower fixtures, which would otherwise be essential if shower or spray were desired at all.

A modification of these fittings, termed "Top-Nozzle Supply and Waste" (Fig. 12), overcomes this objection to the strictly "Bell Supply" type. It has a high nozzle delivery projecting into the tub, and is fitted for spray attachment. The inward projection is much less than with a double cock, which, in a short bathtub, would occupy much needed space. The noise of falling water, obviated with the bell placed low, is the same as with the double cock; and the mixing space, intermediate between that of a cock and the regular bell delivery.

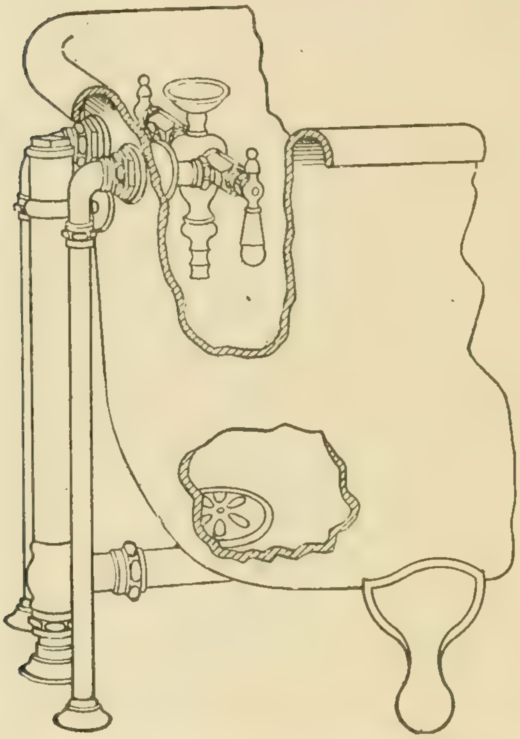


Fig. 10. Common Type of Double Cock and Connected Waste and Overflow.

An element of danger is inherent in a bell-supply outlet placed so low down as to be submerged when the tub is in use. If the supply is opened when the tub contains dirty water, and the pressure of water is lowered by accident or by opening faucets elsewhere, it is quite possible that the fouled water will be drawn back through the bell or nozzle into the supply pipes, thus, perhaps, contaminating the water for domestic use. For this reason, cocks which discharge near the top edge of the fixture, above the level of the water, are increasingly used at present.

For private use, where both children and adults are to be regularly served, the bathtub is the only fixture answering the requirements. As the physical conditions of the members of the family are, or should be, mutually known, and the tub will be regularly cleansed between baths, any possible chance of communicating humors of the skin through the bath can be guarded against. For institutions and general public use, the tub bath is open to serious objections, some of which apply as well to private use. The water for a tub bath is at its best when first drawn into the tub; and the person, before bathing, is certainly in condition to pollute it more or less. As the bathing process nears completion, these conditions are exactly reversed. Tubs used by the public may not be carefully cleansed between times of use, and the bather is ignorant of the condition both of the tub and of the person who used it previously. In institutions for the insane and feeble-minded, unscrupulous attendants have been known to bathe several persons in the same water. Large pools are better, but still not ideal; nor are they always suitable or practicable.

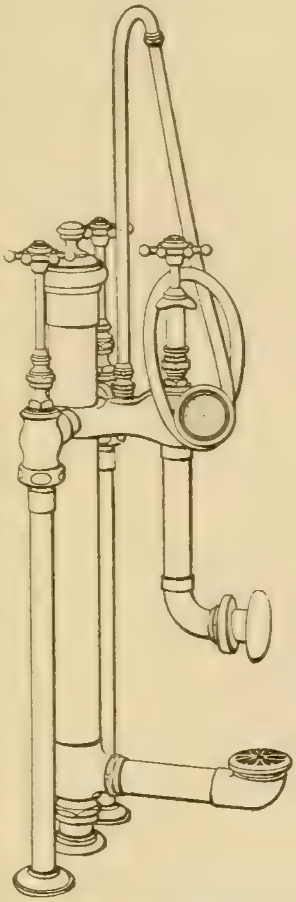


Fig. 11. Bell Supply and Waste Fittings.

Shower Baths. Shower or rain baths are commonly installed in barracks, gymnasiums, and schools, and are no longer unusual in private dwellings. Some of the objections to the tub bath, which have been stated, are entirely avoided by the shower fixture with its supply of running water. Those who have studied the hygienic effects produced by the action of jets or streams on the surface of the body, urge very strongly that the impact results in stimulating the proper action of the skin. This is the opinion of most persons who have had experience with such apparatus.

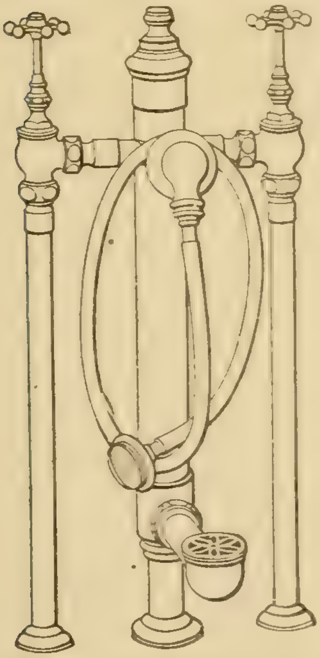


Fig. 12. Top-Nozzle Supply and Waste Fittings.

The older forms of showers, which direct the water vertically upon the head of the bather, are not so desirable as those in which the outlet is inclined and placed at about the level of the shoulders, thus avoiding wetting the head unless desired. Indeed, all the essentials of a bath of this form are met by a water-supplied rubber tube discharging at about the level of the waist over a tight floor or pan provided with a drain.

Aside from the shower baths that may be provided in conjunction with a bathtub, one type of which is shown in Fig. 13, many designs are fitted to floor-pans, called *receptors,* usually having a curtain, as in Fig. 14, thus providing for private installations a great variety of complete showering and spraying appointments. The receptors may be enameled iron, porcelain, or marble. A cement or asphalt floor, sloping to a drain, is simple and effective.

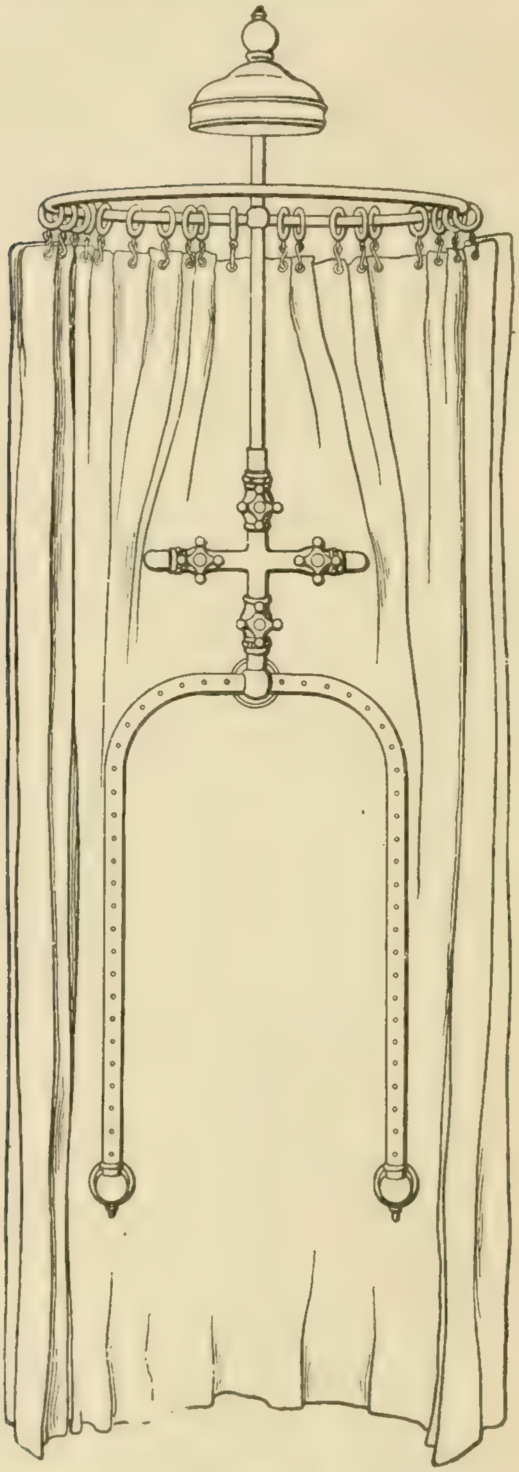


Fig. 13. Type of Shower Bath Provided in Conjunction with Bathtub.

In lieu of the full curtain and regular receptor capable of providing six to eight inches' depth of water, and having tub-like supply and waste fittings in addition to the shower features, a shallow base of marble provided with a drain and having three marble sides, such as is shown in Fig. 15, can be provided with any preferred type of shower fittings. The overhead douche, already noted, set at an angle, with flexible joint for adjustment, as seen in Fig. 16,. so that the body can be played on without wetting the hair, is not often fitted to private shower fixtures, as it requires considerable additional space. A rubber cap for the head enables one to use the vertical shower with a fair degree of satisfaction.

A point concerning shower fixtures and relating to the safety of the user, to which special attention should always be given, is that of the valve arrangement. If the design renders it at all possible, as sometimes is the case, one is apt inadvertently to scald himself by at first turning on hot water alone. The chances of injury in this way increase with elaborate combinations, if not carefully guarded against by the designers; and we should not take it for granted that they have provided such safeguards. As a rule, reliable makers do embody ample mixing chambers, thermometers, etc., in such apparatus, where necessary, and they regulate the control of hot-service valves, or in some other way render the improper use of them unlikely.

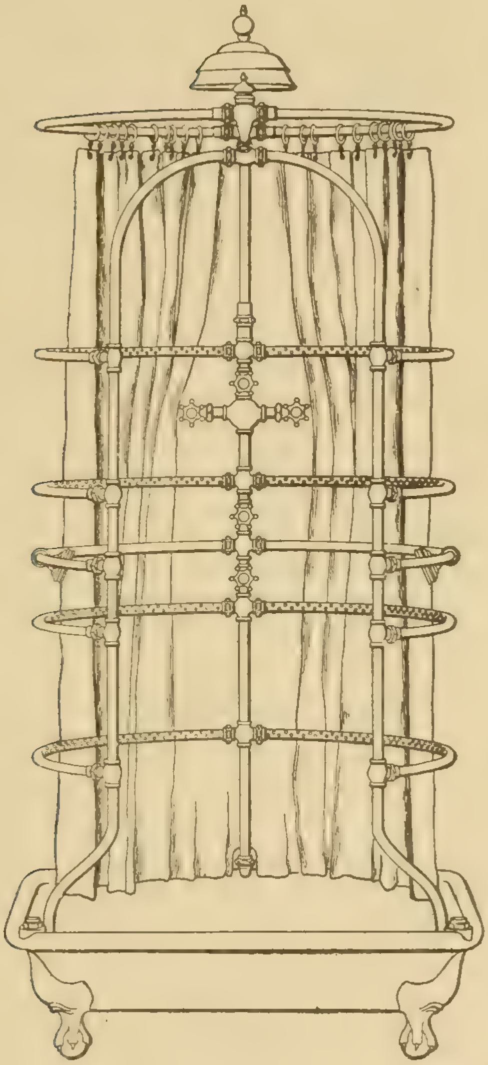


Fig. 14. Shower-Bath, with Curtain Fitted to Receptor.

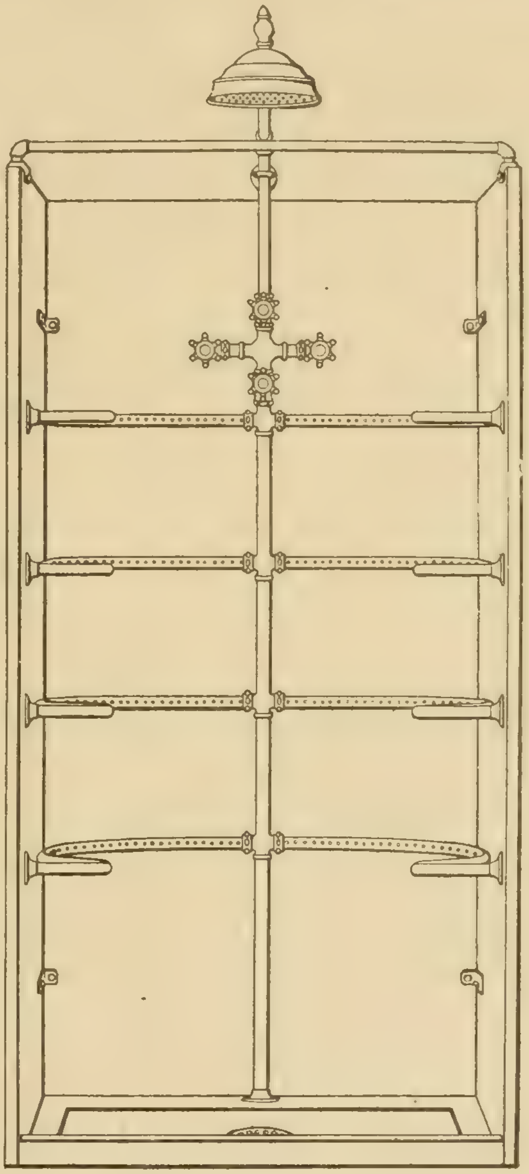


Fig. 15. Shower-Bath with Three Marble Sides and Shallow Marble Base.

Sitz Baths. These are primarily for bathing the hips and loins in a sitting posture, but may be fitted with special features as ordered. Porcelain and enameled iron are the usual materials. The fixtures approximate in dimensions 15 inches in height at front and 26 inches at back, and are 26 to 30 inches wide. In the back, at a proper height, in a complete fixture, like that shown in Fig. 17, is a horizontal slit accommodating fittings for a "Liver Spray"—a wide wave-like spray of water, either hot, cold, or of intermediate temperature, as suits the person. In the bottom, in conjunction with the outlet, is a hot or cold douche, equally under control of the user. In the center of the douche, and operated independently, is a Bidet jet. These provisions are entirely separate from and independent of the regular supply fittings, but one waste fitting is used in common for all. The simple sitz bath has the regular Bell Supply and Waste, like those used on the bath, the dimensions being diminished to suit. For the extraordinary features, these fittings are merely adapted in a way to give the user convenient control. For all but the simplest fixtures, the control appliances are invariably fitted through the rims, the valve handles being provided with proper indices to guide the user. Bidet jets in combination with sitz-bath fittings, have to a great extent curtailed the use of separate Bidet fixtures. Bidet jets have often been added to a water-closet, but a satisfactory application cannot be made to a closet. Separate Bidet fixtures are now rare, but are furnished by

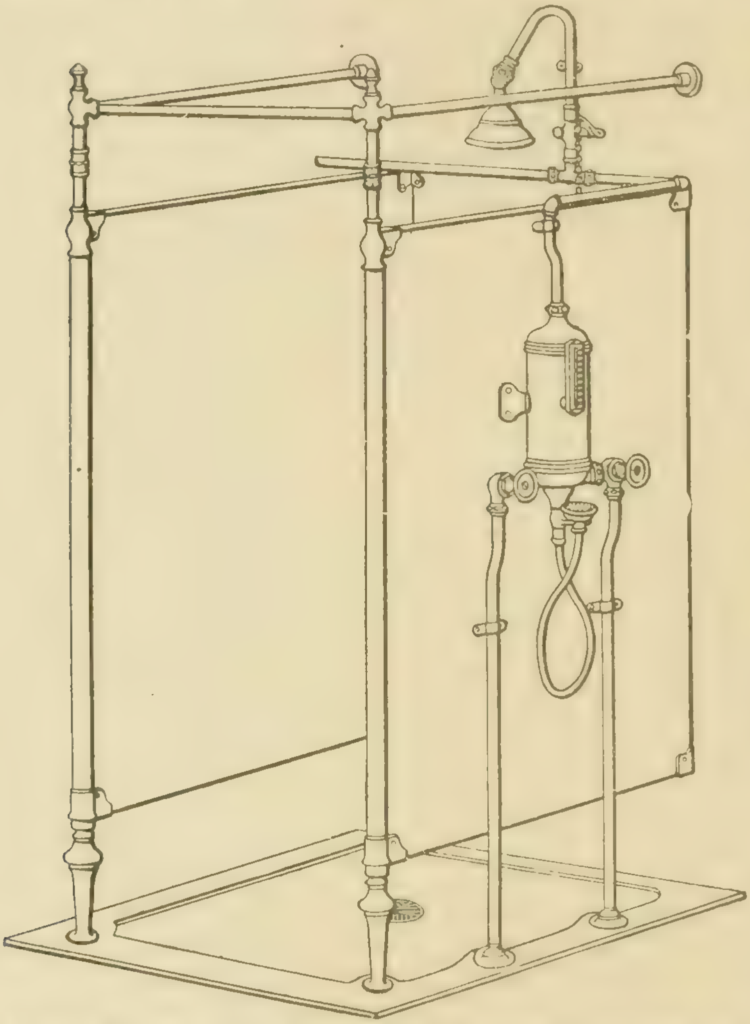
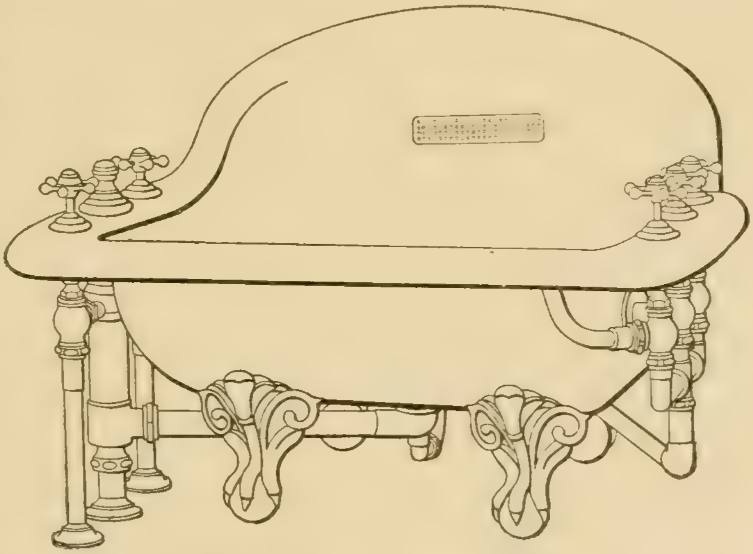


Fig. 16. Shower-Bath Fittings with Overhead Douche Set at an Angle on a Flexible Joint.

fixture makers; and in isolated cases, where frequent or regular use is necessary, are preferable to any combination with a fixture used for other purposes.

The sitz bath is conveniently used for a foot-bath, thus making this fixture doubly useful. Indeed, the sitz bath is a more comfortable means of bathing the feet than is the foot-bath itself. Children's bath-tubs, small, and elevated by legs to the height of a lavatory, are made, but no well-defined demand exists for them. Greater convenience to the nurse, the use of less water, and quicker filling and emptying, are the only points in their favor.

Foot=Baths. The foot-bath is a small rectangular tub with proper feet and rim, furnished with supply and waste of the regular bath pattern, diminished to suit. The sizes average say 12 inches deep, with 20-inch sides. The feet make the total height about 18 inches. Fig. 18 gives a good idea of the usual enameled-iron foot-bath fixture. Enameled iron and porcelain are the usual materials. They require even less water than the sitz bath, but, as before said, are not so convenient for the purpose as the sitz fixture, and are not installed except in the most spacious and elaborate bathrooms. The foot-bath would serve admirably as a child's bath, except that it is too near the floor.



No. 17. Sitz Bath, with Complete Fittings.

Bidet Fixtures. The majority of leading fixture makers do not now catalogue these. They consist essentially of a pedestal like a closet pedestal, with bowl and rim contracted in the center, giving an outline something like the figure 8. Proper fittings to operate the jet and waste are provided. Porcelain is the material. As mentioned before, Bidet jets are furnished in combination with receptor shower fixtures, as well as with sitz baths.

Drinking Fountains. Drinking fountains are now frequently used in stores, schools, and residences, the various fixtures adapted to such installations being readily obtainable. The basins or drip-slabs for public indoor fountains, are often cut to order by the manufacturer; and the cooling and faucet arrangements are provided by the plumber. Porcelain, enameled-iron, and marble fountains of stock designs are made. For schools, trough-like basins, either with open spouts for continuous streams, or with self-closing faucets, as shown in Fig. 19, are frequent. The fixture shown in Fig. 20, consisting of solid porcelain, in which the recessed drain-slab and the high back constitute a single piece, is of recent design, presents an excellent appearance, and has the advantage of being easily kept in immaculate condition. The three deep waste outlets, above each of which is a faucet, afford facilities to many users in a short space of time.

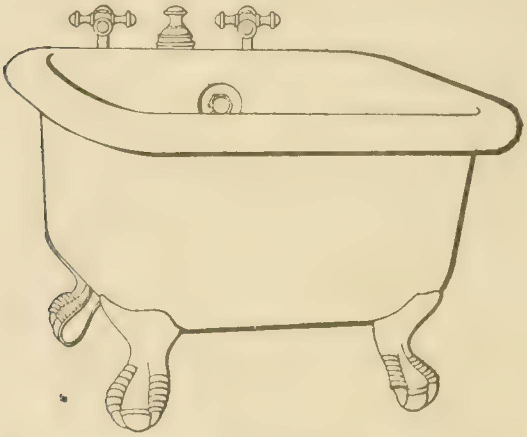


Fig. 18. Common Type of Enameled-Iron Foot-Bath.

One device which serves well for common use, is the ordinary lavatory, provided with a stiff perforated bottom fitting extending well up toward the top of the bowl. This, with a proper faucet on the slab, and a cup-chain fitted to the extra faucet-hole, makes a useful but not attractive fixture.

Recessed porcelain and enameled fountains designed to be placed in wall niches, and having concealed connections, as suggested by Fig. 21, are neat, and require very little room outside the finished wall line. Countersunk slabs with strainer waste, with back either integral or separate, as design or material dictates, are made in marble and porcelain. Marble fountains are adaptable to any location, because the slab and back can be cut to any shape or dimensions preferred. The fountain proper, faucet, cup, and pipe waste connection, with strainer, are all that is supplied by the makers.

A type of fountain shown in Fig. 22, is provided with a flowing jet of water from which one can drink without placing the lips in contact with any metal surface. The small central bowl or cup is constantly submerged and cleansed in the stream of water which passes outwardly over it, thus avoiding the danger incident to the common use of the same drinking cup by many persons. The surface does not afford lodgment to possible germs of disease, which are most liable to transmit contagion when allowed to become dry and adhere to a surface.

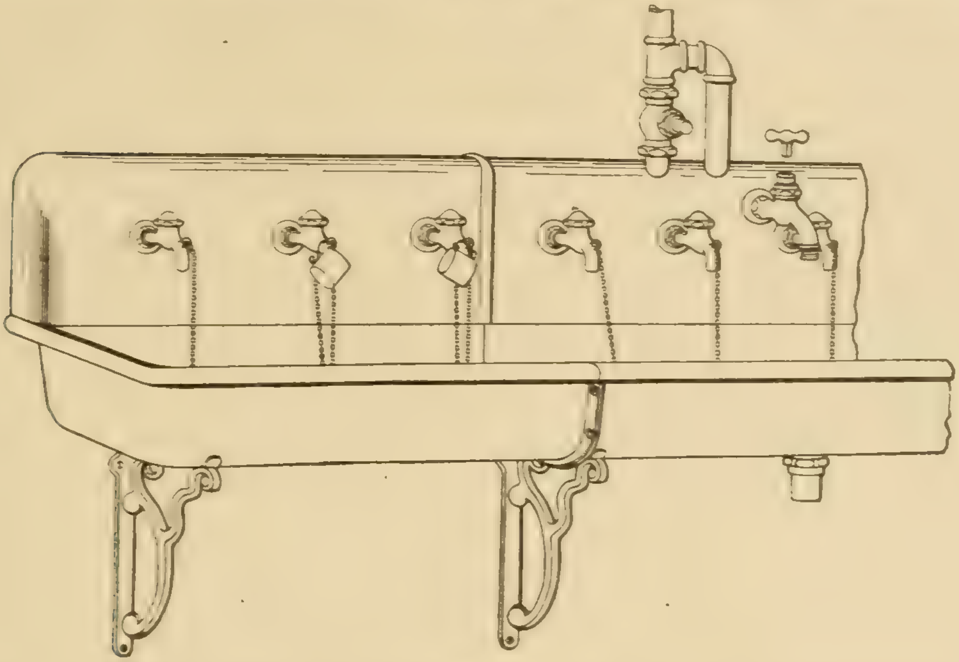


Fig. 19. School Drinking Fountain—Enameled Iron, with Self-Closing Faucet.

Lavatories. Lavatories are made from porcelain, enameled iron, marble, and onyx, in numerous patterns. The number of designs is so large that they are best understood if considered in the classes into which they may be divided. In marble and onyx fixtures, the slab, back, and bowl are necessarily separate pieces. In any but very accurate fitting and erecting, the unavoidable joints soon, if not from the beginning, invite the accumulation of dirt. Poor workmanship, settling, abortive countersinks, and

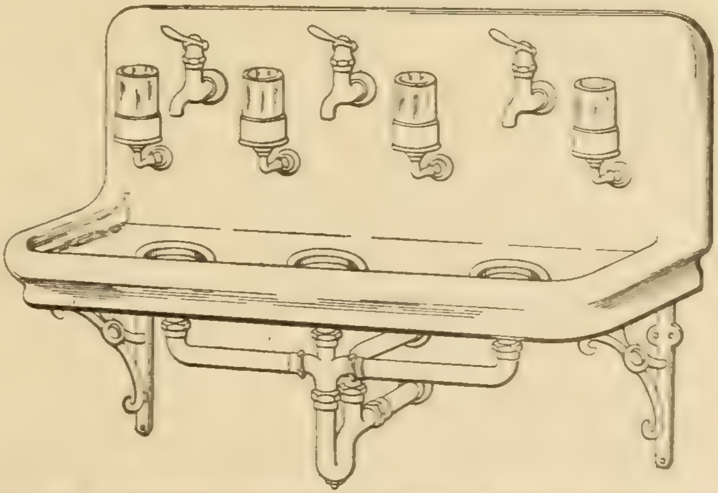


Fig. 20. Porcelain Drinking Fountain. Recessed Drain Slab and High Back in One Piece.

faucet bosses not cut free within the countersink, have in many cases brought slab types of basins into unjust repute, or, at least, have given basis for strong talking points against them, which have been effectively so used. If made and installed in the most approved manner, these styles, properly cared for, offer little reason for severe criticism. One fact, however, must be borne in mind when comparing marble with other materials used for plumbing fixtures—namely, that marble is *not an impermeable stone.* Nearly all marbles (excepting only the very hardest and most dense) are quite absorbent, and depend upon the surface finish given to the

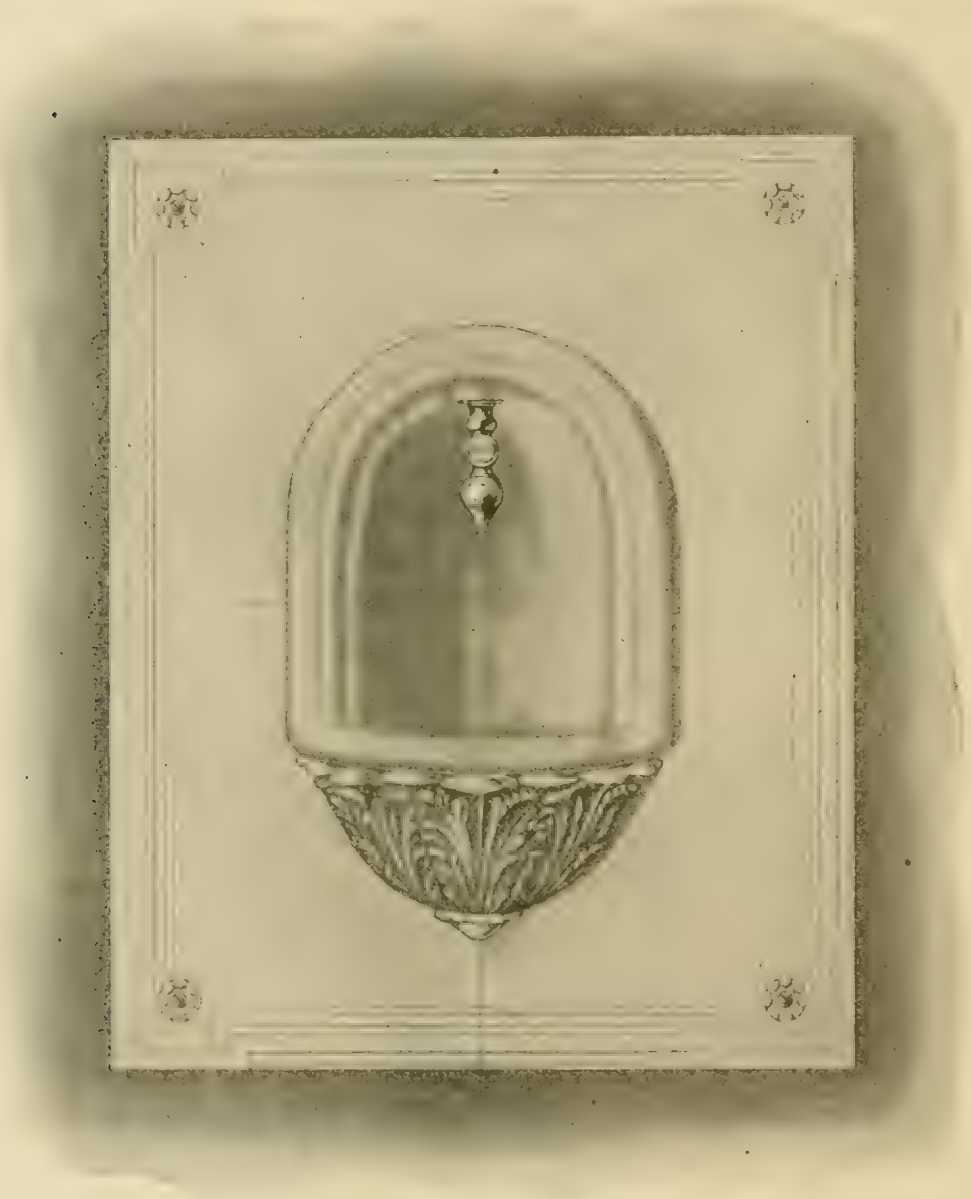


Fig. 21. Porcelain Recessed Drinking Fountain.

slab to resist the entrance of liquids into the body of the stone. As soon as the surface becomes roughened by wear, the greasy and acid wastes penetrate into the pores, and the marble becomes permanently discolored. Only a limited observation of the bad condition of marble floors or urinal slabs which have been subjected to use for a few years, is necessary to confirm this statement.

Ordinary Tennessee, Veined Italian, Hawkins County Tennessee, and Statuary Italian marble, range in cost in the order mentioned. Fancy imported marbles and onyx are much more expensive. Tennessee marble varies in color from grayish brown to very dark reddish brown, uniformly intermixed with light specks. The Hawkins County marble is bright reddish and white-mottled. All the ordinary materials are cut in stock sizes, and may also be had to order, like the more costly, in any size and shape desired.

The type with apron or skirting, shown in Fig. 23, has legs, and the slab is supported continuously by the skirting. In those supported by brackets or leg-brackets, the strength of the slab is depended upon for support between the bearings. Legs, brackets, and all other metal trimmings should be in keeping with the character and cost of the stone slab. If brackets are properly spaced, the weight is so balanced as to leave very little sagging strain on the center of the slab. A shelf of marble, or a mirror with marble frame, or both, may be fitted above the back as a part of the fixture.

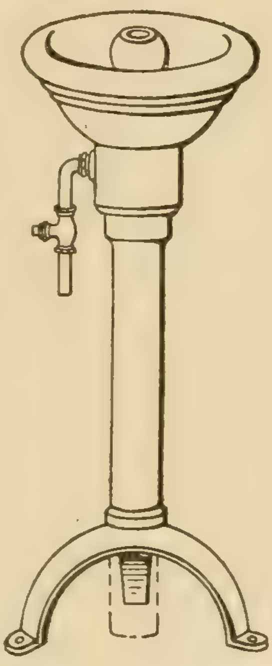


Fig. 22. Drinking Fountain. No Cup Necessary.

Porcelain and enameled-iron lavatories have bowl, back apron, and soap-cup in one piece. The pedestal of the lavatory illustrated in Fig. 24 is separate, of course, and no back is required, but the general features of integral construction are shown. There are no joints to open. The only injury possible to them is the marring or fracture of the glaze or enamel. Porcelain and iron lavatories, unlike those of marble, are adapted to pedestal support; and some very desirable patterns are therefore made in these materials only. Neither pedestal nor wall lavatories are suitable for use, except where the wall or wainscoting is of marble, tile, or some other waterproof material.

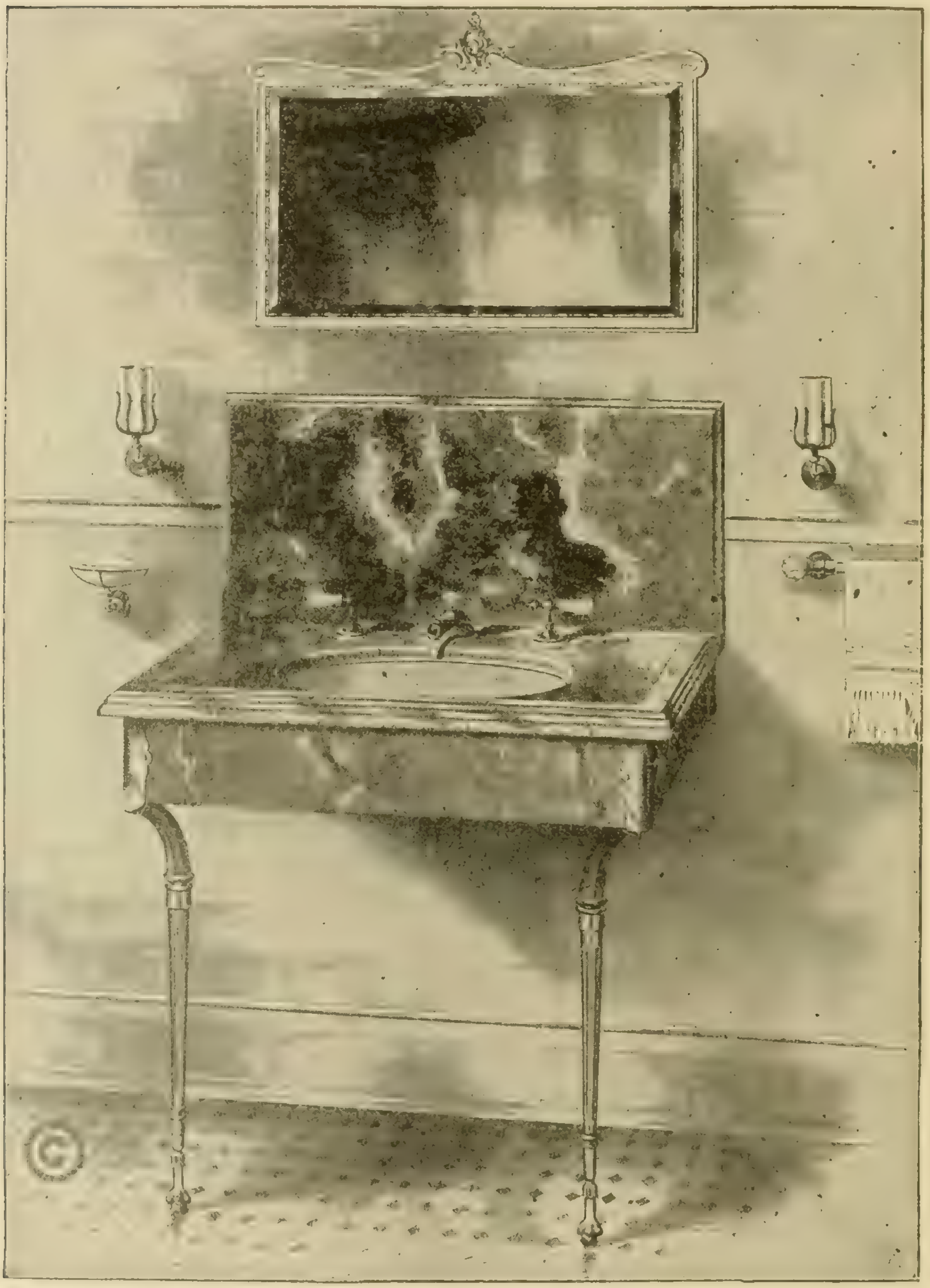


Fig. 23. Brazilian Agate Slab Lavatory, with Apron and Legs.

To provide for leaving the floor clear and free of obstruction, lavatories supported on brackets or hangers, as indicated in Fig. 25, with supply, waste, and ventilating pipes fitted on or into the wall, are best. If found practicable, a neater job results if all pipes leading to and from pedestal lavatories are carried through the pedestal. A supply and waste run to the floor is generally far easier and cheaper to secure than the fitting of all pipes to the wall.

The purchaser seeking iron or porcelain fixtures, has no choice of styles beyond that which the market regularly affords. If he prefers the workable materials, he should insist upon certain features of design which are essential to the best service. Abrupt edges and sharp corners should be avoided; the slab ought to be at least $1\frac{1}{2}$ inches thick, and the back not less than 12 inches high; the general dimensions must be as liberal as space will allow or the service demands (not less than 22 by 32 inches for a 14 by 17-inch bowl); the countersinking must be deep, $\frac{3}{16}$ to $\frac{1}{4}$ inch; the faucet bosses must not join the general border level at all; the faucets must not be less than 12 inches apart, nor so near the bowl that it will be difficult to secure them to the slab; nor may they be placed so close to the back as to make repairing troublesome with any type of Fuller faucets; the joint surface of the bowl must be ground to fit the slab, and provided with not less than four well-drilled anchor-holes for clamps to secure it.

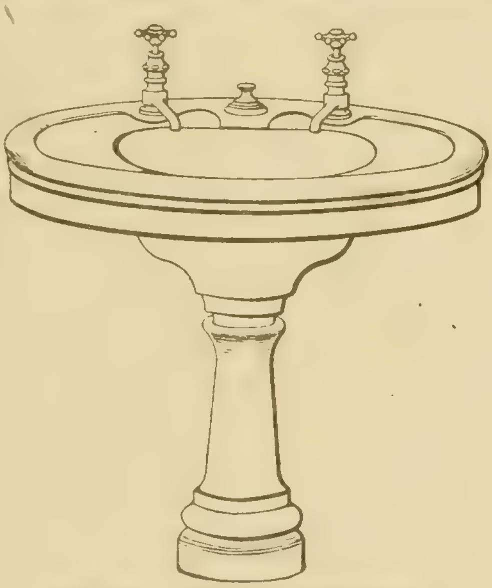


Fig. 24. Lavatory on Pedestal.

Round bowls were formerly quite generally in use, but are now almost relegated to memory. The width of slab needed for a roomy, round bowl is too great; and at best the arms of the user must be cramped in a somewhat vertical and awkward position, while the smaller sizes are very uncomfortable in this respect. The sudden opening of the faucet when the bowl is empty, is likely to ricochet water with annoying results. This is caused by the water striking the curved bowl surface at a tangent, and is not peculiar to the circular bowl; the oval or crescent, or, indeed, any shape of bowl that presents a curved surface to which the faucet stream is tangent, favors the same result; the ovals in integral fixtures are the most annoying. Marble and onyx have an advantage over porcelain and enameled lavatories so far as ricocheting is concerned. The opening in the slab is not so large as the bowl, and thus a horizontal overhanging ledge is formed all around, above the bowl, which generally intercepts the water in a way to keep it off the floor and person. Porcelain and enameled fixtures have not this virtue. The bowl surface, being integral with the slab, is uninterrupted and continuous; hence ricocheting is more violent with them than is possible with the separate bowl.

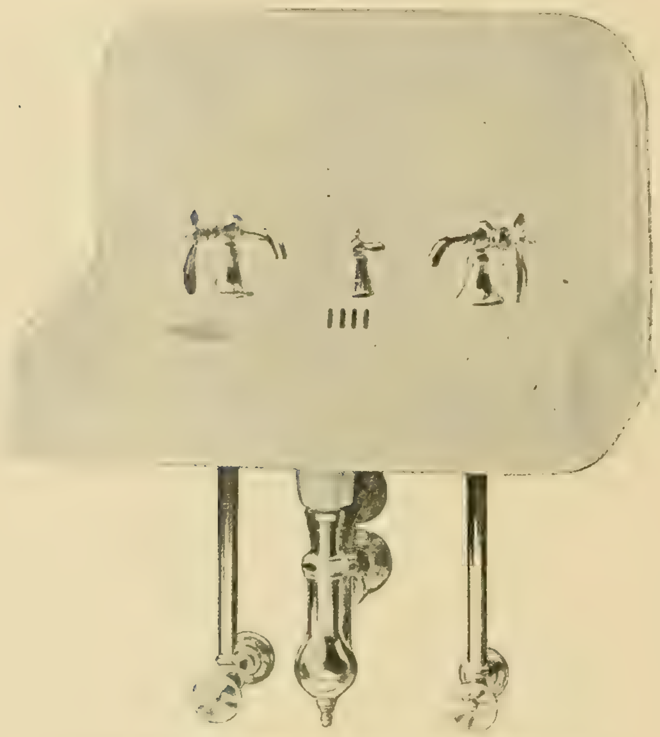
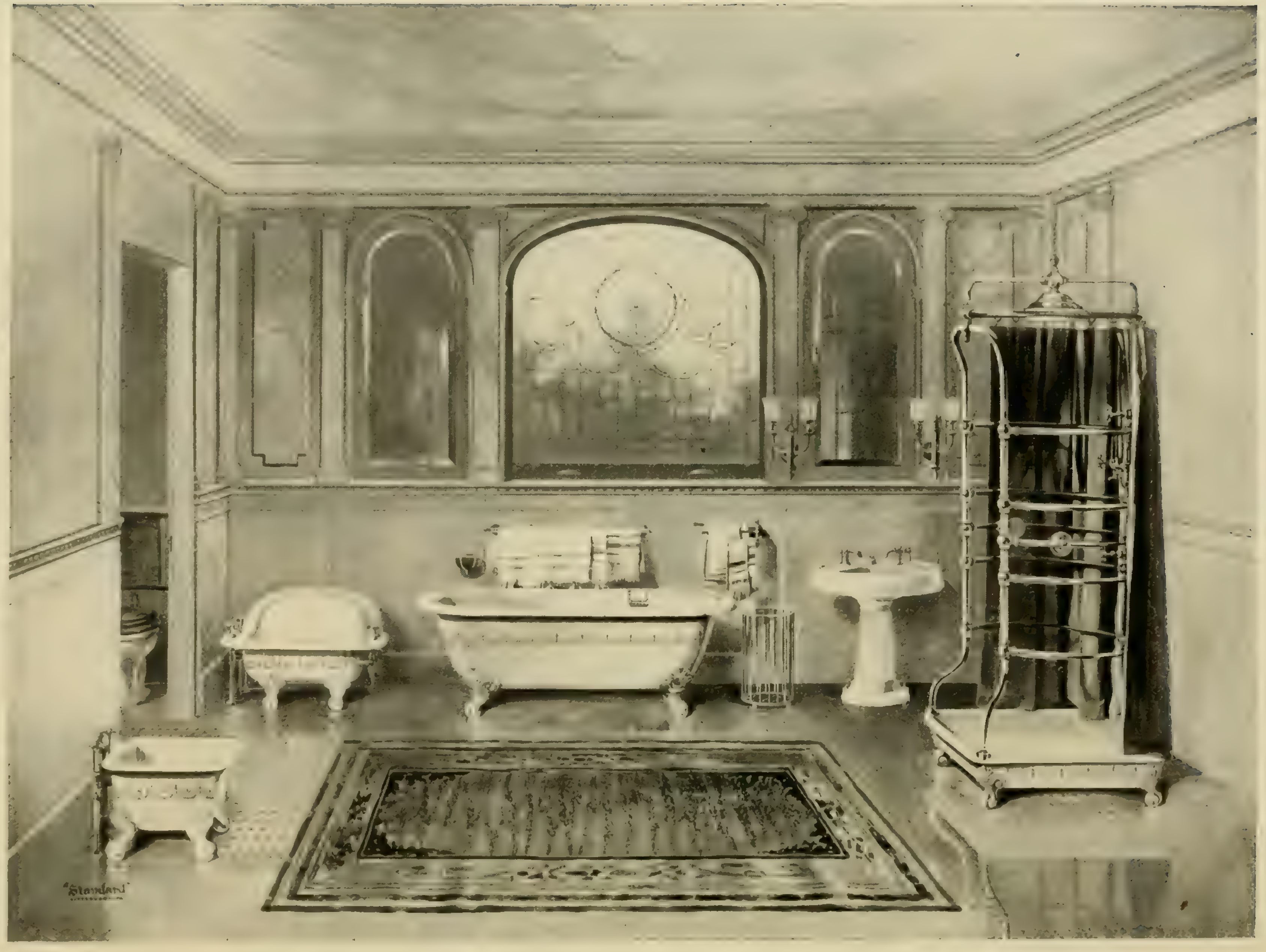


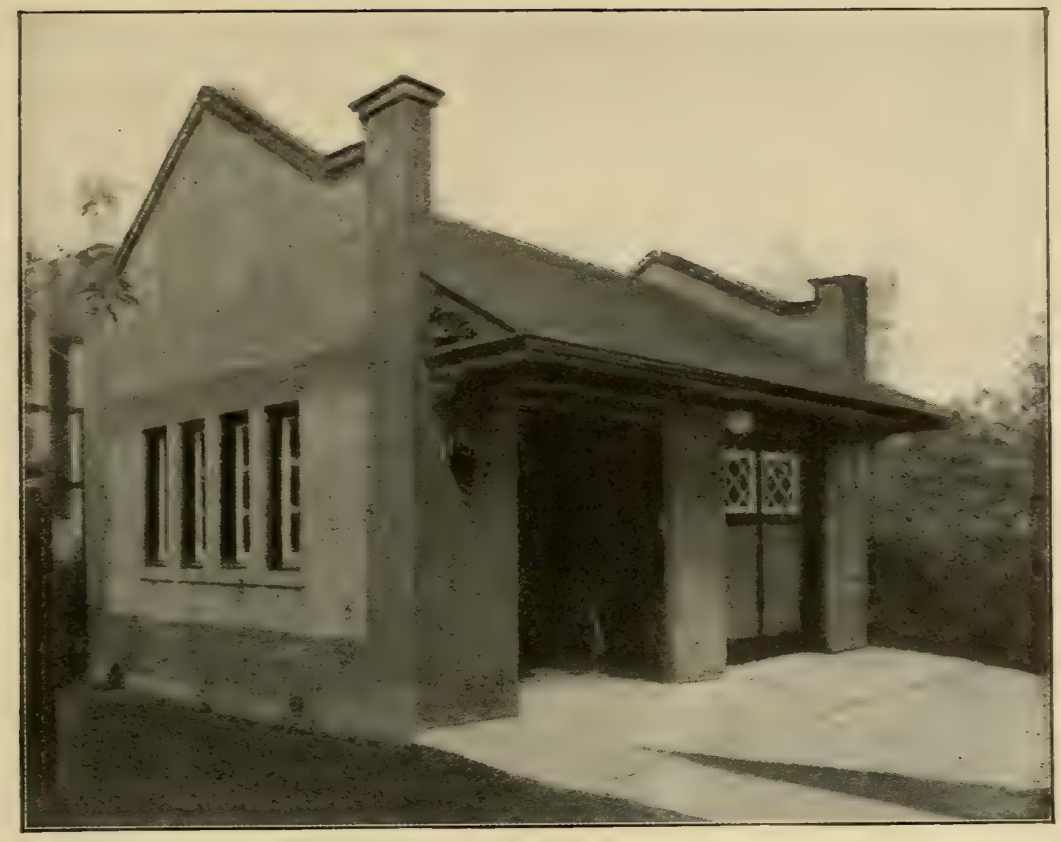
Fig. 25. Lavatory Supported on Brackets.

Oval bowls are now in general use on all types of lavatories. They employ slab space to the best advantage, and are the most convenient for use. The crescent or kidney shape, illustrated in Fig. 26, is, however, as far superior to the simple oval bowl as the oval is to the round. It permits the forearms to lie in a natural and most convenient position when dipping water to lave the face. This form of bowl should be accompanied with a scalloped or recessed front. The D-shaped bowl, and other bowls embracing the prime feature of the D-shape, while not so graceful in appearance, are, without exception, to be preferred, on the score of utter absence of ricocheting when the faucets are properly placed. The D-shape, a transverse section of which is shown in Fig. 27, has a semi-oval front, with the end lines continued parallel some distance past the major axis, and with a straight-line back nearly vertical. This form gives a nearly flat surface in the bottom between the back wall and major axis, on

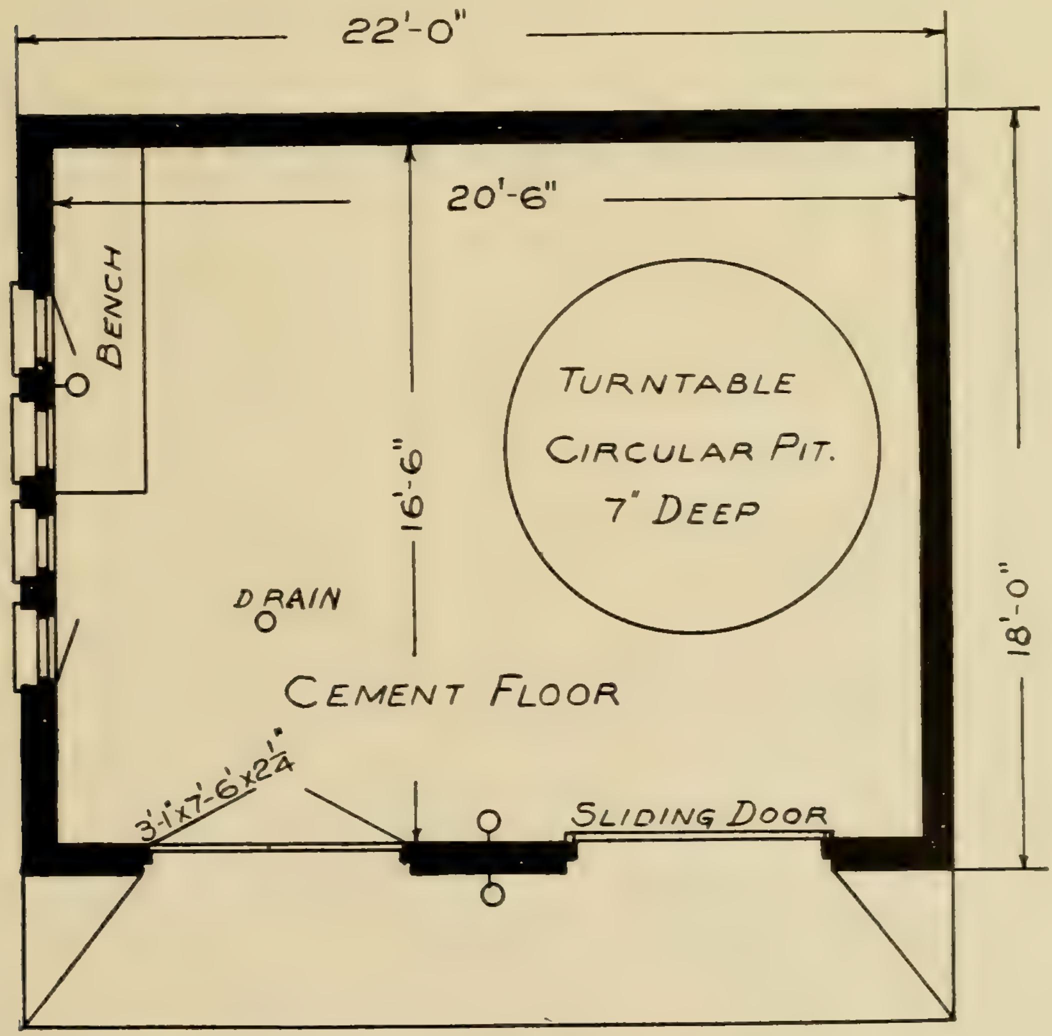


TYPE OF MODERN AMERICAN BATH ROOM WITH LATEST APPROVED FITTINGS.

The Federal Company.



Walls of Common Brick with Red Mortar Joints and Trimmed with Red Brick.
Slate Roof.



EXAMPLE OF DOUBLE GARAGE FOR E. D. WEARY, CHICAGO, ILL.
W. Carbys Zimmerman, Architect, Chicago, Ill.
Built in 1904.

which surface the stream strikes and breaks when the bowl is empty. A depth of water is quickly formed under the stream, which checks any spraying or spattering.

The traps used for lavatories are lead or brass (either cast or tubes), or combinations of these materials, plain or vented or of anti-siphon design. One trouble with lavatory trap ventilation, is the difficulty of obtaining a vertical rise directly above the trap. These vent connections should be carried as nearly vertical as possible, as high at least as the bottom of the lavatory slab, before any horizontal run is made; otherwise the choking of the waste pipe would float solid matters into places from which gravity would not dislodge them. In the absence of water-wash in the vent pipe, these solids would obstruct the vent and defeat its purpose. This danger is not given due attention by many plumbers. The patent and horn overflow bowls, with plug and chain, are the cheapest effective means of controlling the overflow and waste from the bowl. The standing waste, of essentially the same design as the waste fitting for a bathtub, with the body fitting projecting through the slab at the rear of the bowl, is perhaps the most satisfactory waste and overflow arrangement. Various schemes for operating basin stoppers by means of levers and swivels, are employed; but none of them has come into more than limited use.

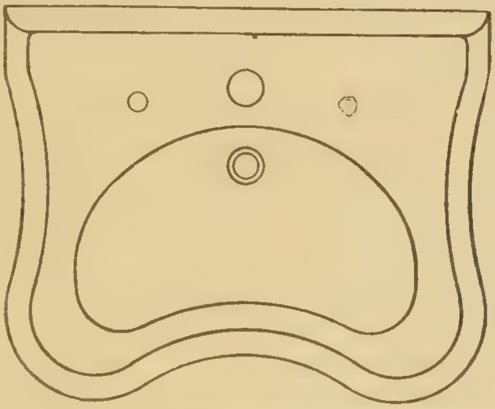


Fig. 26. Plan of Lavatory Slab with Crescent or Kidney-Shaped Bowl.

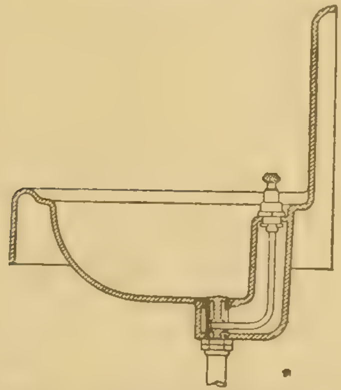


Fig. 27. Transverse Section of D-Shaped Lavatory Bowl.

Basin faucets, aside from special designs, are made on three general operating principles—(1) screw-compression; (2) eccentric action without springs; and (3) self-closing. They are also made in two types—with regular and low-down nozzles. All of these are represented in Fig. 28. The regular type has the nozzle some distance above the base flange, and screws into, or is cast on, the body. The low-down type has its nozzle with a flat bottom, hugging the slab as closely as practicable. The objection to the low-down is the inaccessible narrow space between the nozzle and slab, which becomes filthy and is difficult to clean. High, projecting nozzles obstruct the space over the bowl, especially when washing the hair, but are otherwise most satisfactory. The high nozzle gives trouble with patterns of faucets that separate in the body for repairs, such as the Fuller type, which closes rapidly with pressure. The fault, however, is often that the slab is so shallow as to necessitate the faucets being placed too close to the back to turn without removing the nozzles. If these are cast on, removal of the whole faucet is required before it can be separated. Some faucets are made with union joint in the body, thus avoiding such trouble; but these are not widely used.

The false economy which often dictates the purchase of a small slab, generally also prevails in the selection of its trimmings. Compression faucets close against the pressure, and are slow in action, causing practically no reaction. They are generally responsible for the omission of air-chambers on supplies of medium pressure. On account of their slow action, they are suitable for high pressures although but little weight is given this fact by the trade. The features essential to good, lasting service in the compression faucet, are: a cross-handle, a stuffing box, a raised seat, and a swivel disc. Self-closing faucets of various patterns are made with a view to preventing waste of water, the intention being to compel the user to hold the faucet open only as long as water is needed, and to insure automatic closing when it is released. There are none such except the crown-handled, that an ingenious person cannot find means to hold open at will; yet, withal, self-closing faucets are of great value in reducing wastage. A rabbit-eared faucet can be kept open by placing a ring over the handles while squeezed together; the telegraph bibb, by weighting down or tying up the lever; and the T-handled, while not so easily controlled, can be tied open by a lever secured to the handle. The crown-handled design can be operated with ease by the hand of the user, but does not readily lend itself to unauthorized control by means of a mechanical stop. Self-closing faucets require strong and well-designed springs to close them against the force of the water. They have sometimes come into disrepute through leakage for lack of adequacy in this feature of their construction.

Lavatory supports should have positive means of leveling the slab, such as set screws, screw-dowels, or whatever adjustment the kind of lavatory and support may be best suited to. Lavatory brackets are generally at fault in having limited bearing at the bottom of the wall-face. This point of the bracket is where all the strain is thrown against the wall, and the effect is noticeable if the upper end springs away ever so little. Full-length brackets are not open to this criticism, but they interfere with the washboard or other finish next the floor.

Sinks. These are made in four general classes according to the purpose to be served—namely, Kitchen, Pantry, Slop, and Factory or Wash-Sinks. The materials used are:—Porcelain; enameled, galvanized, and painted cast iron; enameled, galvanized, and painted wrought iron; brown glazed ware; copper; slate; soapstone; various compositions; and occasionally wood. Porcelain and enameled cast iron are most used, galvanized and painted sinks being confined principally to factory use. Sinks of extreme length, in one piece, as shown in Fig. 29, or sectional, 6 to 8 inches deep, with supply and faucets over the center line or at the side, belong to the factory class. These are usually provided with a flat rim, rest on pedestals, and are not over 24 inches wide. There are also roll-rim patterns, with bracket support and iron back, and with faucets fitted through the back. These are generally 8 inches deep and about 20 inches wide.

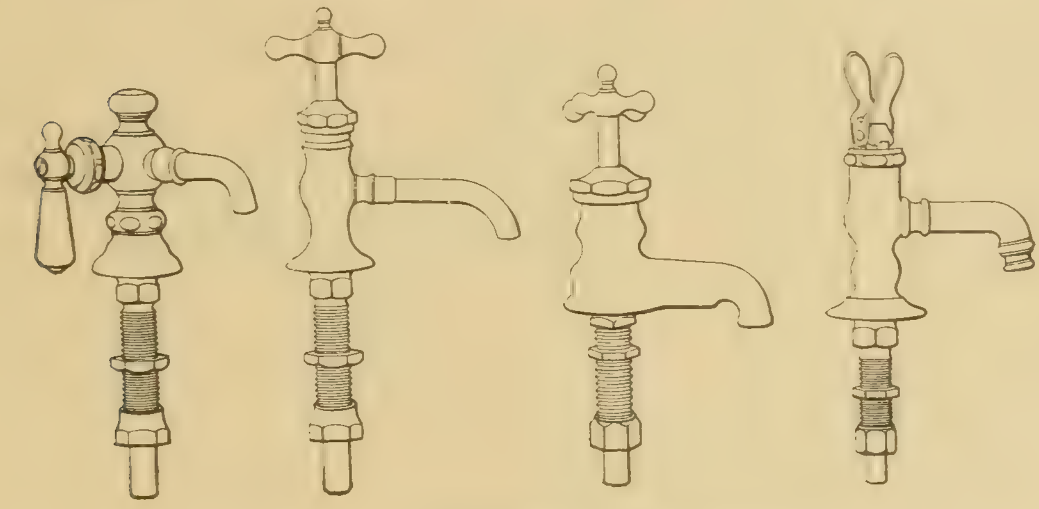


Fig. 28. Common Types of Basin Faucets.

Kitchen sinks vary in size according to general requirements. Common sizes are 18 by 30 inches and 20 by 30 inches. The depth ranges from 6 to 7 inches. There are two types of iron sink—flat-rim, with outlet at end; and roll-rim, with outlet in center. Neither style of outlet is always desirable as to connection; but the center outlet drains more directly. The flat-rim type is not provided with legs. Cast legs were formerly furnished, being attached to the sink by slipping into dovetails. When legs are desired for this type, the plumber provides gas-pipe legs, with or without a top frame. Iron splash-backs are provided for flat-rim sinks, but not of the deep pattern in which air-chambers may be cast. Plumbers drill these sink rims to attach brackets or legs, and sometimes also to secure to them hardwood capping or drainboard. Hardwood drainboards are generally provided by the plumber's carpenter. Hardwood splash-backs, set free of the wall to permit circulation of air behind the fixture, are also provided. Sometimes marble splash-backs are provided. Marble is best, but is not in keeping with a flat-rim sink. The back may extend to the end of the drainboard, or merely cover the length of the sink. Omitting the back behind the drainboard, as represented in Fig. 30, is often thought desirable. The drainboard should be free of the wall when the back is not extended. Iron sinks, with roll rim on front and ends, are furnished with drainboards suited to attach to either or both ends. These may be added as an after-consideration, or changed from side to side at will, if there is but one drainboard, or removed entirely, without marring the looks or service of the sink. This interchangeability commends itself to both plumber and customer.

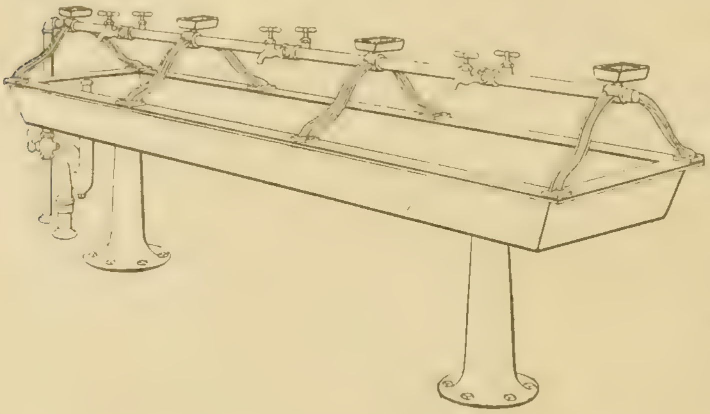


Fig. 29. Long Wash-Sink for Factory Use.

Roll-rim sinks, with the end recessed to receive a drainboard, are also made, which give good service, but in any subsequent change of location require setting in the original relative position.

Wooden drainboards, with an iron end to attach to sink, and enameled-iron drainboards, are furnished if ordered.

Open strainers are most frequently fitted to sinks, in which case the sink cannot be then used for washing dishes, but merely serves as a support for dishpans and other vessels and as a catch-all for drippings from the drainer. Hence the open-strainer sink must be large enough to accommodate suitable washpans, etc., while one fitted with a plug-strainer should be relatively small if it is designed to use the sink proper as a washpan.

The use of wooden sinks in large installations, such as hotel kitchens and restaurants, is not unusual, the theory of their use being that less breakage of crockery occurs, by reason of the softness of the material. The argument against the use of wood is not given due weight in this connection. The well-recognized objection to any porous, absorptive material which retains moisture and is subject to decomposition, is especially to be considered in the use of wood for greasy wastes. For the reason mentioned, wood is never a suitable material for this use.

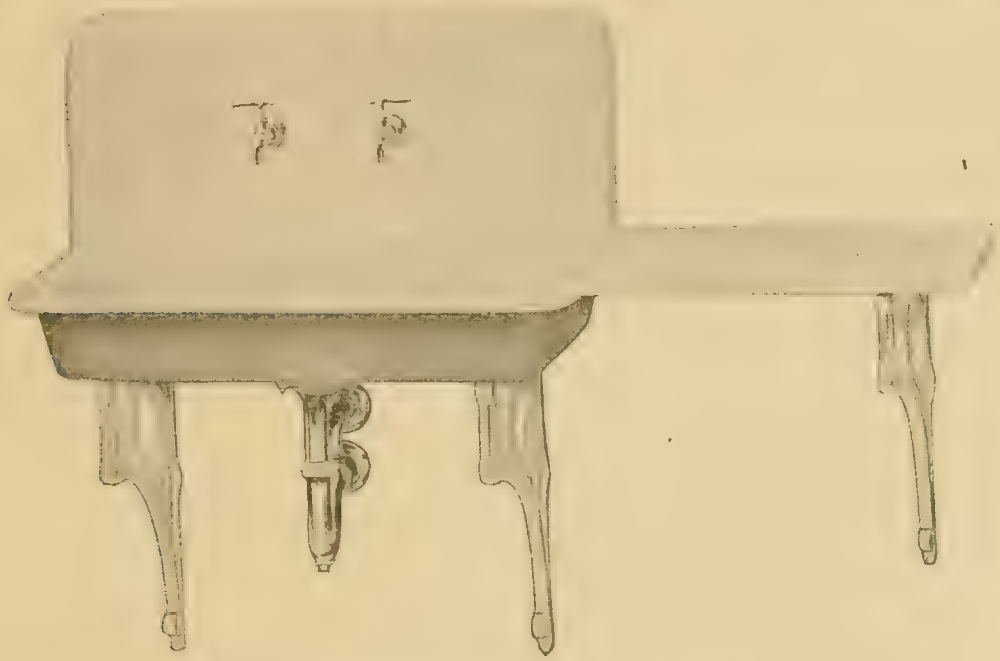


Fig. 30. Enameled-Iron Kitchen Sink Supported on Brackets. Splash-Back Omitted behind Drainboard.

Rubber mats are essential for both sinks and drainboards having enameled or glazed surfaces, in order to avoid accidental injury to the articles cleansed. As a matter of fact, the average dwelling has but one sink, which serves both kitchen and pantry purposes. Dual service is not always satisfactory, however, as no sink can be well adapted to both uses for a large family. A plug-strainer sink should also be provided with an overflow.

Porcelain and iron sinks have generally been supplied with loose backs; but sinks of one piece—that is, with sink and back integral—are now obtainable. Sinks with integral apron or skirting all around, to be placed free of the wall, are suitable for installation where the wall is waterproof.

Sinks are built from slabs of natural stone as desired, and may be with or without drainboard or skirting. They are generally provided with a high splash-back. These sinks are not limited to the patterns of a moulding room, and easily keep pace with the desires of the purchasers. Selection is confined to a choice of material, as every desirable type of fixture is easily supplied.

In the use of any natural stone, such as slate or soapstone, for plumbing fixtures, and especially for sinks, it should not be forgotten that angles and rectangular corners are with difficulty maintained entirely free from deposit. Although the flat surface can be readily scoured, it is always difficult to clean the sharp angles and corners satisfactorily. The difficulty is increased by the fact that some plastic jointing material, such as putty or cement, must be used in putting together the fixture; and small fragments of this material project into the angles and render the corners rough. Stone and porcelain sinks are heavy, and require careful packing for shipment.

Air-chambers may be cast in iron sink-backs. The ordinary sink-back is not well suited to the convenience of the plumber where supplies to any fixtures pass up behind the sink. The faucet-holes cannot be changed, and slots for pipe are not provided at the top edge. Sawing these gaps after the goods are enameled, leaves the fixture with an unfinished appearance. The proportion of shank to the handle of faucets of the Fuller pattern used on sink-backs, must be such that the handles will turn straight back.

A popular fixture of comparatively late design, adapted for small dwellings and now made in the cheaper materials, is the kitchen sink in combination with a single laundry tray, an example of which is shown in Fig. 31. In this, the drainboard serves as a cover for the tray when the sink is in use. Sinks have also been supplied in combination with lavatories, one sink being placed in the center or at the end of a battery of lavatories.

A pantry sink (Fig. 32) should always be provided with a drainboard. It is a smaller fixture than the kitchen sink, and is nearly always of the plug-strainer and overflow type. Its faucets are generally of the high-nozzle type, like those for shampoo purposes, but of smaller capacity and better adapted to rinsing than are kitchen-sink faucets. Indeed, the pantry sink proper need not necessarily differ at all from sinks used for other purposes. Every feature of its trimmings and setting is intended to best serve the butler's needs.

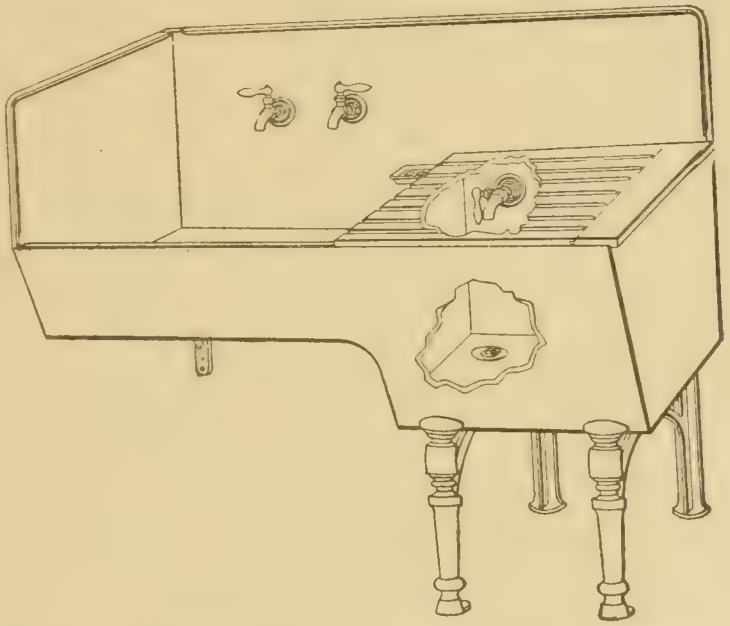


Fig. 31. Kitchen Sink and Single Laundry Tray Combined.

The waste matter from the butler's sink is not like that from the kitchen sink; hence the waste pipe is not necessarily so large, nor is a grease-trap so badly needed. Grease in considerable quantities finds its way into kitchen-sink waste pipes. It floats on the stream of waste water as it travels through the pipe, and, being always next the interior surface, either adheres thereto on contact, or by a reduction in temperature is chilled and congealed, thus clinging to the pipe walls. Successive layers of grease are in this way accumulated, and the bore of the pipe is finally reduced so much that solid matter easily completes the stoppage. Forcing out, and then filling the pipe with boiling lye water, and again flushing with hot water, will usually remove most of the obstruction. Sometimes the lye loosens the grease in chunks, which clog the pipe seriously at the first favoring point, and the pipe must then be cleaned manually.

When once choked with grease, the pipe must ultimately be opened and cleaned by hand, often at material expense when long lines are deep underground. To avoid this trouble, various traps (of which two examples are shown in Fig. 33) have been designed to separate and collect the grease, either by flotation or by chilling—generally by the former. Traps to collect the grease by flotation were formerly improvised by the plumber, being placed in the drainpipe just outside the building. This location left too much pipe subject to choking between the grease-trap and the sink; and the trap itself often became a generator of bad odors in warm weather.

The grease-traps now commonly furnished are placed in the kitchen under the sink, and frequently serve as the regular trap for the fixture. The grease is easily removed by lifting out the container or by skimming from the top. Hinged bolts with thumb-nuts secure the covers so that they can be easily and quickly opened and securely closed.

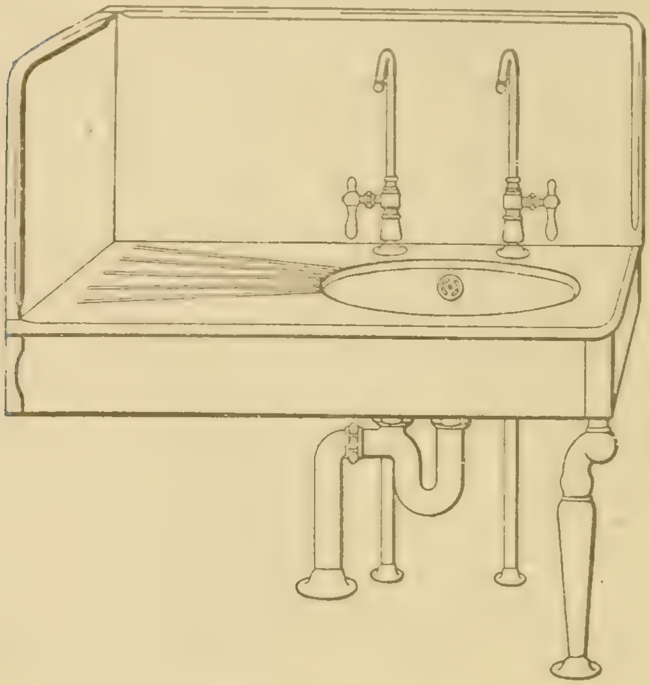


Fig. 32. Pantry Sink.

Traps which chill the grease are not used so much as those acting by simple flotation, but they do the work perfectly. The chilling proccess is accomplished by means of a water jacket through which the cold-water supply passes. The water entering low, surrounds the wall of the pot trap within, and passes out high up on the opposite side (see fixture at left in Fig. 33). Circulation—or, rather, change of water—in the jacket, is dependent on the amount of water used at the fixtures.

The usual slop sink is 18 by 22 inches and about 12 inches deep. Generally it is furnished mounted on a trap standard, as in Fig. 34, which serves the double purpose of support and waste-trap.

Care should be taken before installing a fixture placed upon a trap standard, to examine carefully whether the seal of the trap is provided for by suitable interior partitions. It is not uncommon to find defects in the casting, if of iron or brass—or in the porcelain, if of that material—which would seriously affect the maintenance of the water seal. In fact, it is desirable in connection with slop sinks, as with all other fixtures, that the trap be of such a form as to show clearly, even after being set in place, the position of the various portions which constitute the trap and maintain the water seal.

The waste pipe is never less in diameter than 2 inches, and is usually 3 or 4 inches. The outlet is invariably through an open strainer.

Slop sinks are made in all the materials common to other fixtures except natural stone. These sinks are to the chambermaid what the kitchen sink is to the cook. The shape and liberal-sized waste are well adapted to removing slop and scrub water. In the complete fixture, the sink is provided with an elevated tank and flushing rim, to cleanse the fixture walls; also with hot and cold supplies for drawing water, rinsing mops, etc. The supplies usually connect between the valves, and terminate with a long spout with pail-hook and brace. The spout supports the pail over the center of the sink while filling. The ordinary slop sink is provided with hot and cold faucets; and as the rims of the cheaper kinds are plain flanges, no tank flushing is possible.

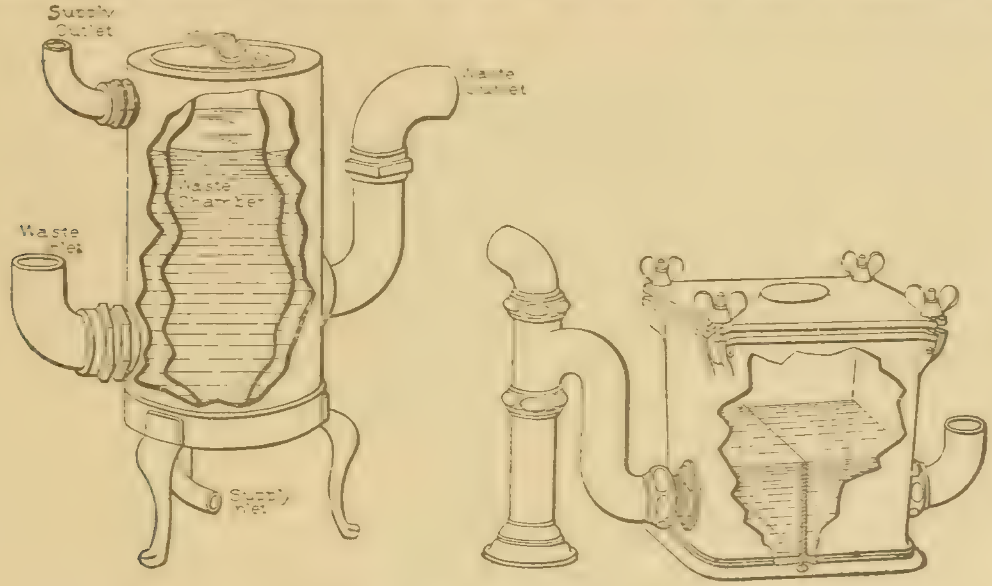


Fig. 33. Types of Kitchen Sink Traps for Separating and Collecting Grease.

Laundry Trays. These are made in all the materials used in other plumbing fixtures. Wood trays were formerly common but their unfitness because of absorption and odors, coupled with the increase in cost of lumber and the lessening in cost of the better materials, has effectually driven them out of the business.

The same inherent objection to the use of wooden covers may be urged as to the use of that material for the body of the fixture.

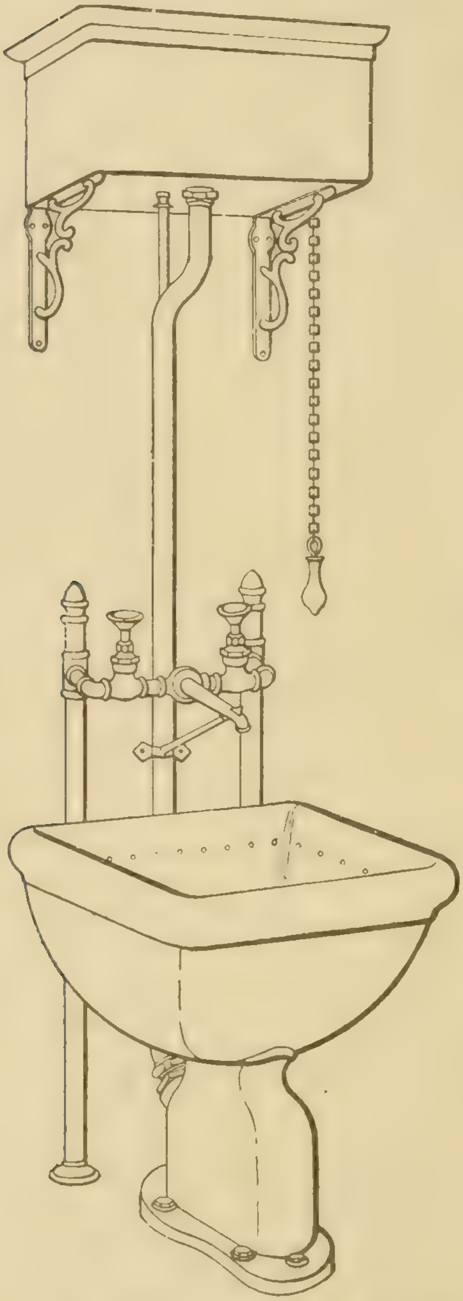


Fig. 31. Slop Sink Mounted on Trap Standard.

Trays are made singly and otherwise, but generally used in sets of two or three, except in the combination with sink already described. They are supported by a center standard or a metal frame, as best suits the material used.

Some means of attaching wringers are provided, if possible. The waste is usually 2-inch. One trap answers for a set of trays. The size approximates 26 by 30 inches at top, with 15 inches' depth. The walls are all vertical except the front, which inclines about 30 degrees, making the width at bottom considerably less than at top. Some makers furnish one tray with each set, designed to serve as a washboard, the interior of the front wall being corrugated like the surface of a portable washboard. The inclination of the front is about right for scrubbing, whether the tray or an ordinary board is used, and the supports place the top of trays convenient to the work.

All trays were formerly made with faucet-holes in the back; and the plumber furnished a hinged cover. Side-handle faucets were necessary to allow the cover to close, as holes for top-handle faucets would be so low as to make useless too much of the space above them. The faucet-holes were seldom fitted water-tight. Holes are not now made in trays unless ordered, and the side-handle wash-tray bibb is disappearing. They were always annoying. If placed with the handles right and left as intended, the seat could not be examined, and no reaming or dressing of the faucet seat could be done without removing the faucet. When placed with the faucet handles facing each other, they were wrong-handed and too close together. It was awkward to supply air-chambers—especially so when all the faucet holes were equidistant from the top. When placed for one line of supply above the other, one line of holes was too low. These objections combined brought about the practice of omitting the covers, putting the supplies over the trays, and using regular sink faucets. Overflows are provided only when so ordered.

Enameled backs with air-chambers and faucets are supplied with roll-rim enameled-iron trays. A complete set of three trays, with all attachments and fittings, is shown in Fig. 35. Flat-rim trays are made with or without faucet-holes, and are intended to have a hardwood frame to secure them rigidly. The wood frame and cover can be had with the fixture, but the plumber often supplies them. Nickel-plated or plain brass wastes and traps are furnished for trays, but the plumber can provide lead or cast-iron waste, if wanted.

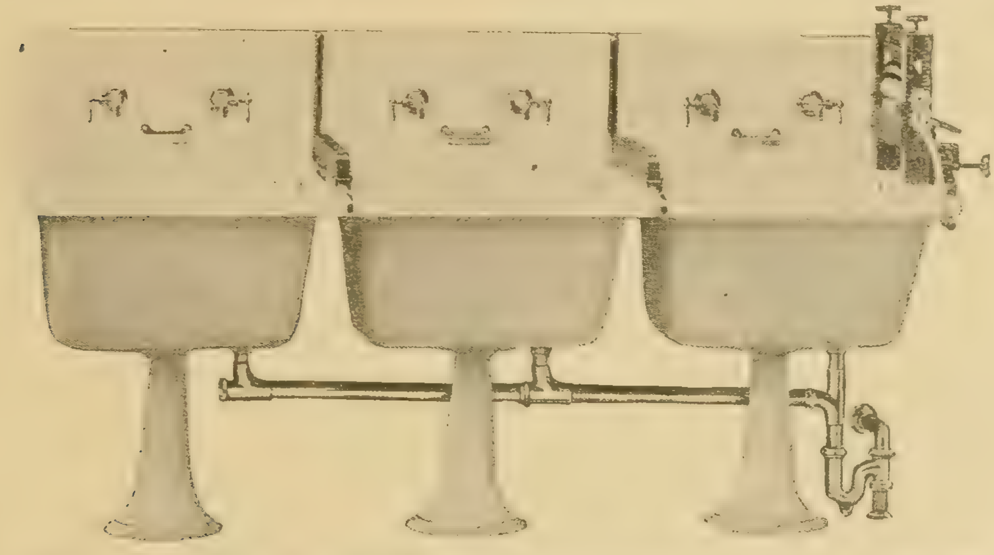


Fig. 35. Set of Three Laundry Trays, with complete attachments and Fittings.

Water-Closets. Types of water-closets are innumerable, and are separable into classes according to principles of action. Porcelain and painted or enameled iron are the materials used. Porcelain is more fragile, but has the better finish and is susceptible of a greater variety of design and ornamentation. The all-vitreous body of water-closet china of to-day is far superior to the glazed clay ware of the past, which, depending only on surface impermeability, soon cracked badly, thus permitting of absorption, the forerunner of odors which no plumber's skill could prevent. Enameled iron has not so durable a surface, but will stand rough usage, and has the advantage of very seldom cracking from frost even though the water in the trap freezes.

The greater relative advantage and durability of the porcelain closet over the best qualities of enameled-iron fixtures, should not be overlooked. There is less adherence of the foul wastes to a porcelain surface than to the enameled surface. It is also a fact that enamel is subject more or less to abrasion by the use of harsh scouring materials, as well as to decomposition by uric acid and water-closet discharges, and is therefore not a very durable material. These statements can be confirmed by observation of closets which have been in use for a number of years.

Iron closets of the better forms are used most in public places, stores, warehouses, etc. The pan closet, of iron, with earthenware bowl, is not now installed. For these, a trap was placed under the floor. The pan, operated by the same lever as the flushing valve, retained water, partially sealing the body from the bowl. The flush was by the swirling of a stream which entered tangentially under the rim. The bowls were round, as is necessary in all hopper closets thus washed, for water will not swirl in an oval bowl.

The objection to the pan water-closet is principally due to the fact that the outer bowl or container is a receptacle of filth which can never be properly cleansed. When the pan deposits its contents in the lower portion of the fixture, a considerable amount of the filth is spattered upon the walls and is not subject to the cleansing effect of the stream of water which scours only the upper bowl. When the closet is operated, the odors from this concealed surface permeate the room in an objectionable manner.

Tall round hoppers with swirling supply are yet frequently used in outhouses and other exposed places. No other form of closet will stand such locations under like conditions. The waste-trap is not placed immediately under the hopper, as in other forms, but down below the freezing depth—five feet as a rule. The supply valve is also placed below freezing, and is operated by a pull or by seat-action. These closets are *continuous* or *after-wash*, according to the style of valve used. Such an outfit is the simple frost-proof closet of the market. Tall oval hoppers with valve and slotted spud attached, swirl or rather direct the water sideways in both directions, but not effectively. The tank supply is also inefficient when delivered through a slotted spud under the common flanged rim. Short oval and round hoppers, with valve or tank supply operated by a pull or by seat-action, fitted to "S," "$\frac{3}{4}$ S," and "$\frac{1}{2}$ S" or "P" traps, for lead or iron pipe floor connection, make up several hundred closet combinations, each differing in some respect from the others. These are the poorest types of water-closet.

A sectional view of the *Combined Hopper and Trap* pedestal of to-day is shown in Fig. 36. It is made in one piece, in both porcelain and enameled iron. This form resulted from the separate hopper and trap fixtures before mentioned. The combined form has oval bowl and flushing rim for tank supply.

The *Wash-out* closet is a modification of the combined hopper and trap, being formed with a dipping bed under the mouth of the bowl, which retains enough water to keep soil from sticking to the surface. The water-bed makes it necessary to discharge the contents at either front or rear of bowl. The back-outlet wash-out is most repulsive to view; in them the drop-leg, which the flush never washes thoroughly, is always in view, so that its filthy condition suggests cleansing by hand. The front-outlet wash-out, shown in section in Fig. 37, is of more inviting appearance; but the drop-leg, although hidden, is there just the same.

Both the Wash-out and the Combined Hopper and Trap types have one fault in common. The trap almost always contains the soil from one usage. When the contents of the trap are flushed out after using, sometimes a similar mass refills it. Of course, two or three consecutive flushes would leave comparatively clean water in the trap, but this is not to be expected in regular usage.

On certain occasions the wash-out may serve a useful purpose on account of the water-bed. The stools of children or the sick may thus be easily observed at the will of the physician or at the discretion of those in charge, while such is impossible where the soil is submerged at once.

Pneumatic Siphon closets of various types have been put on the market. A good example of the type requiring two traps with an air-space between, is shown in Fig. 38. A specially constructed flushing tank is connected with the air-space between the traps. The falling of the flush water creates a partial vacuum in the bottom compartment of the tank, which induces siphonage of the bowl contents.

To maintain a plenum in the flushing compartment of the tank while the flush water is flowing down and into the closet, the air between the traps is extracted, being drawn up through the air-pipe into the tank. Atmospheric pressure in the room simply presses the water out of the bowl and upper trap when the pressure below it is sufficiently reduced. This water, in motion, added to that of the lower trap which has been drawn above its normal level in response to the vacuum, is sufficient to form the long leg of an ordinary siphon; and thus both traps would be entirely emptied were it not for the vent in the crown of the lower trap breaking the siphonage in time to save a water seal for the lower trap.

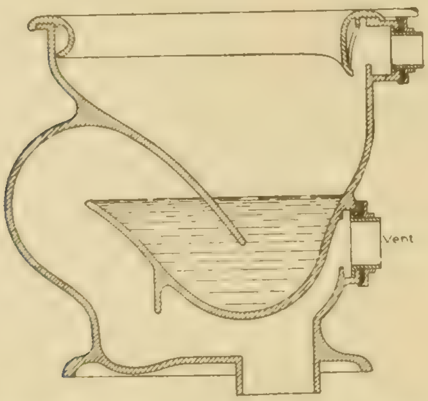


Fig. 36. Section of Combined Hopper and Trap Closet.

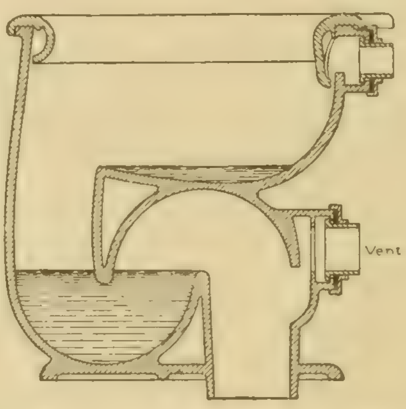


Fig. 37. Section of Front Outlet Wash-Out Closet.

The upper trap with water visible in the closet bowl in repose, is supplied by the *after-fill*, thus establishing conditions for the next action. The lower trap of such closets must be back-vented, and it is essential that the upper trap have no back vent.

The proper action of the tank is necessary to operate a pneumatic closet. A closet constructed on any other principle can be flushed with a bucket, by hand, if its tank is out of order. When a pneumatic closet, however, gets contrary, pouring water into the bowl, simply fills or overflows it. The outlet is air-bound, and no passage of water to the soil pipe can take place until the barrier of air between the traps is removed.

The closets now accorded first place and generally used in the best work, are of the *Jet-Siphon* type, illustrated by the sectional view, Fig. 39. These use more water than is necessary to flush other kinds of closets, because a portion of the water is employed to produce the siphonage. A channel leading from the flush-water inlet to the bottom of the trap, conveys a stream of water to the trap leg, and injects it upward therein. The water in the channel has considerable velocity, and, being discharged into the water in the trap, imparts its energy to the whole mass, which, aided by the rise due to the incoming water from the flushing rim, moves upward at an increased speed depending on the ratio of mass and jet. When the water in the trap has been lifted in this way to an extent where sufficient of it can fall over the weir into the out-leg of the trap, a siphonic movement begins, and true siphonage finally takes place, the cessation of which depends upon the lack of sufficient water to continue it. Before the closet tank is emptied, siphonage often sweeps out the trap thoroughly; and what water falls back into the bowl when the siphon breaks, together with the incoming jet and flush, causes a second siphonage.

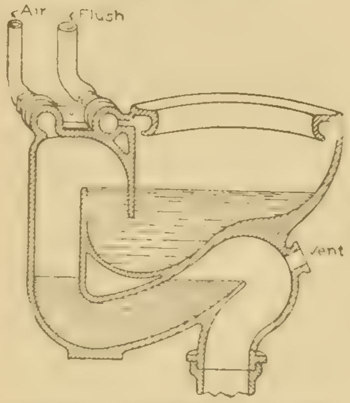


Fig. 38. Section of Pneumatic Siphon Closet, with Two Traps and Intervening Air-Space.

Accuracy in pointing the jet and in shaping the surfaces of its environment, are essential. If the surface above the jet-hole favors interference by the water flowing from the bowl, siphonage will be delayed and abortive, and may not take place at all. So, also, if the jet is not directed so as to maintain approximate concentricity in its travel through the mass of water, its energy is not expended to advantage, and failure is likely.

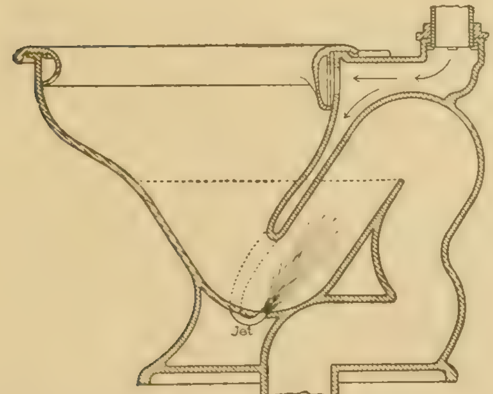


Fig. 39. Section of Jet-Siphon Closet.

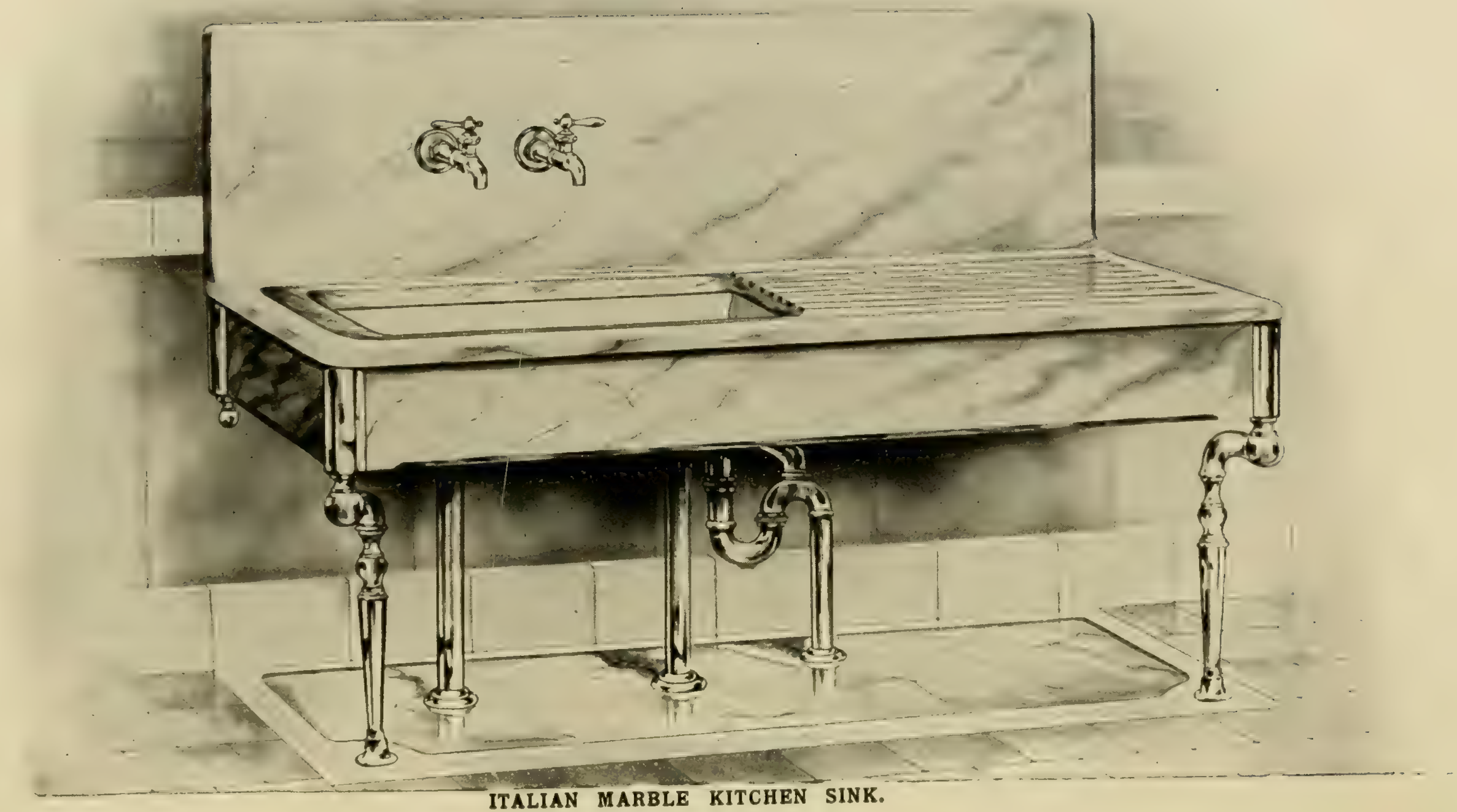
There is no excuse for iron closets not siphoning perfectly. The iron pattern can be altered until it gives the best effect in practice, after which all closets cast from it should do the same. With porcelain ware, however, every closet made requires the same skill in design; and notwithstanding how perfectly the closet may be formed and the jet-hole cut, shrinkage in the kiln during the drying and burning process is apt to warp the wall and change the product so that it will not act properly. Closets of both materials, apparently perfect, often fail when first tried after installation, owing to foreign matter or fragments of enamel, clay, or iron lodging in the jet and changing its action. Usually these obstructions are easily removed by the plumber.

The jet principle has been added to the Combined Hopper and Trap closet before mentioned, producing in it a siphonic action resulting in very much improved service over that of the simple form. With the jet-action, the Combined Hopper and Trap is generally termed a *Wash-Down Siphon.* The so-called "jet" is applied in two ways. In some makes, the flush rim has an extra large and specially formed fan-wash feature, which directs down the back wall of the bowl a sluice-like stream. This stream, in addition to wetting the paper and forcing it down into the water, where it will be promptly carried out, sweeps round the curve of the bowl outlet in such a way as to lend its force to the water in the trap to produce apparent and not infrequently true siphonage.

Another form of the wash-down siphon is provided with a channel from the flush inlet, down outside the back wall of the bowl, to near or even below the water-level in the bowl, where the jet enters through a slit. The action is much the same as with the special fan-wash mentioned, but is generally superior in siphonic effectiveness.

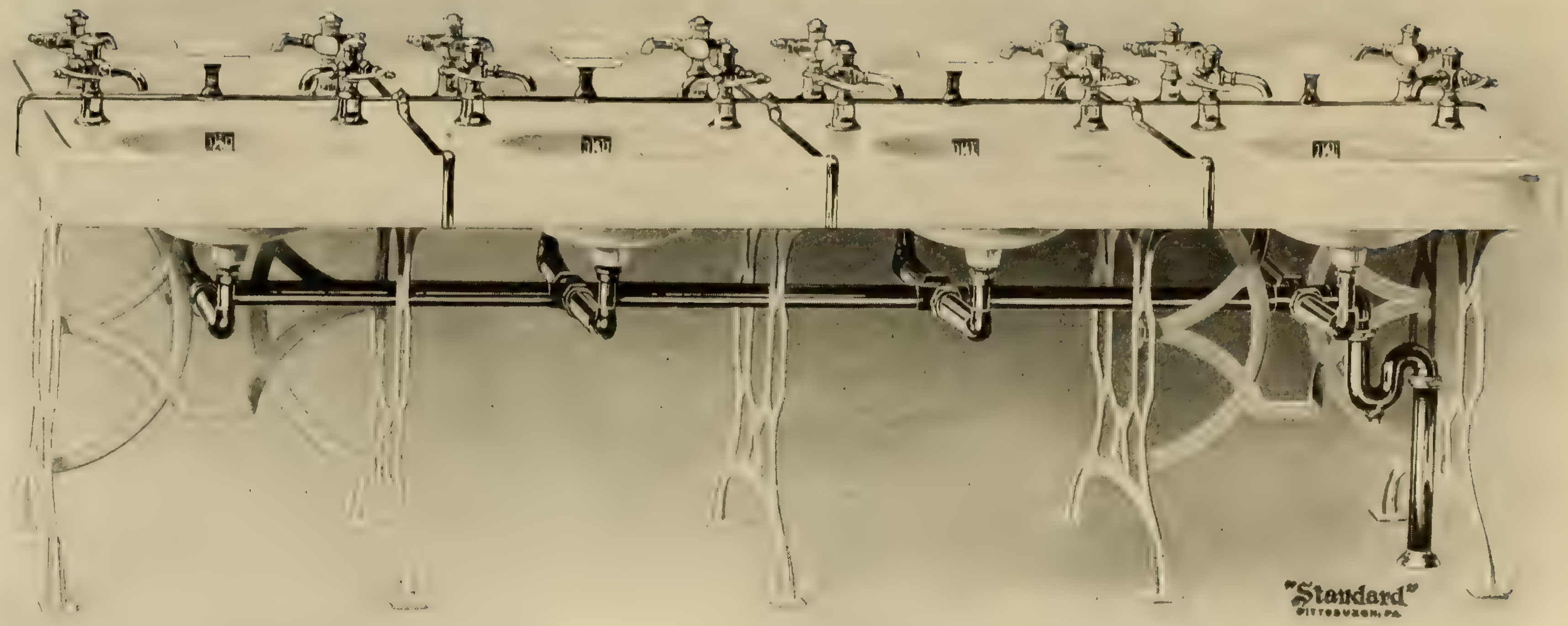
Jet-siphon closets are not provided with vent openings in the closet proper, except for the local bowl ventilation. Wash-out traps are, or should be, vented. The simple hopper and trap should be vented in the trap. Wash-down siphons, generally, are not vented, but it is permissible to vent them low down in the outlet leg of the trap.

All closets for indoor use should have flushing rims. In all earthenware closets and in some forms of iron closets, the rims are made integral; but the iron rims are, as a rule, separate pieces, forming a water channel around the bowl. The bottom, inner edge of the iron rim hugs the wall of the bowl as closely as practicable, and the bulk of the water falls through regularly spaced serrations. Various provisions in the shape of barriers opposite the flush inlet, per-



ITALIAN MARBLE KITCHEN SINK.

The Federal Company.



PORCELAIN ENAMELED PANDORA DESIGN DOUBLE SECTIONAL LAVATORY
Standard Sanitary Mfg. Co.

forated race-way shelves along the rim above the exit openings, etc., are made to insure the rim filling and flushing properly all around.

All kinds of closets were formerly made without regard to the kind of seat to be used. Boxed-in cabinet seats, self-supporting, were universal. These gave way to seat and frame, with wall and leg support. To-day closets are commonly made with base flanges designed to support the weight of the person, and are provided with lugs or seat-shelf for attaching the seat directly to the bowl, as seen in Fig. 40. Metal post hinges are best in every way, if well made and strong. The competition goods, however—made to sell rather than use—*are* so light as neither to keep the seat in place nor to aid in holding it together under the severe strain. The hinged wood-cleat seats bolted to the closet are strong, but are objectionable because they cannot be kept dry or clean under the cleat.

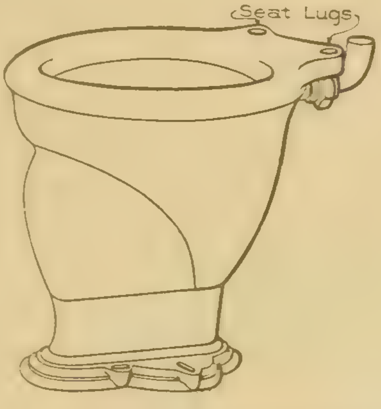


Fig. 40. Closet with Base Flange Support, and with Lugs for Attaching Seat.

Closets are operated with pull or push-button tanks requiring the attention of the user; and are also made of the seat-action type. Children are likely to be forgetful, and visitors to public toilet rooms indifferent, to such an extent that automatic closets are desirable for public places and schools.

Closets are fitted with two styles of tanks—one placed about 7 feet from the floor and serving with a flush pipe never more than 1½ inches in diameter; and the other placed low down, as close to the bowl as connections will permit. Examples of the *high-tank* and *low-tank* arrangements are shown in Figs. 41 and 42, respectively. The low tanks are wider and deeper than the high style, but do not extend out from the wall so much. The low position delivers the water at much less velocity than the elevated style, and, to secure the utmost speed and the volume necessary, the flush connection is never less than 2-inch in a low-tank closet. The rim and jet channel are proportionately larger in bowls intended for use with low tanks. High tanks are about 17 by 9 by 10 inches. Sheet lead and sheet copper are used for closet-tank linings. Some kinds of water, through galvanic action, attack the soldering of the seams in copper-lined tanks with more effect than where lead alone is used. Generally, however, copper-lined tanks give satisfaction if the copper is heavy enough (12 to 16 oz.) and properly put in. Some makers lock-seam the linings water-tight, and solder on the outside before placing the copper in the wood case.

On account of the greater depth of low tanks, swelling of the wood case has, doubtless, been the cause of most of the trouble experienced with this type. When put together in the factory, the wood is very dry, and after being used for a short time, increases in height as a result of swelling from dampness. If the lining be tacked to the wood at bottom and top, injury is sure to result. If tacked at the top only, the copper will soon be supporting the water without help except where the connections are attached. It is now the practice to omit fastening the lining. Very great care has been found necessary with ball cocks for low tanks, in order to secure proper after-fill, the flush connection being too short to aid much in resealing the bowl with its drainings.

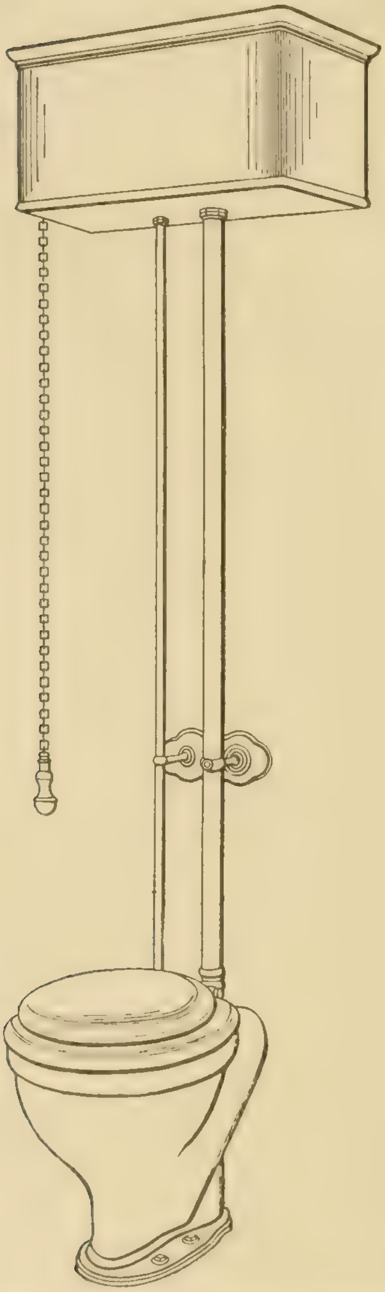


Fig. 41. High-Tank Arrangement of Closet Fixtures.

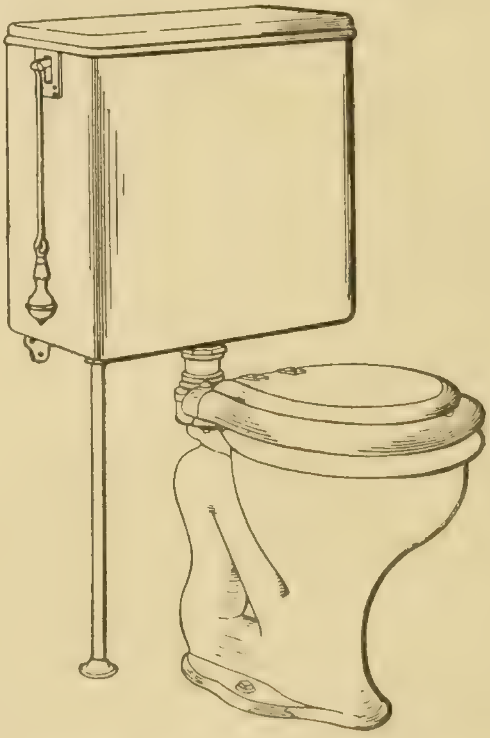


Fig. 42. Low-Tank Arrangement of Closet Fixtures.

Low tanks flush with much less noise than high ones, and permit placing the closet under windows and low ceilings. Low ones require more width on account of the tank, and more depth from the wall to the front, as the seat and lid must be placed far enough forward to be thrown back and remain leaning against the front of the tank. Low tanks are provided with ventilated covers; while the high pattern, which is out of children's reach, is left open at the top. The fewer working parts in a tank, the less likely it is to get out of order.

A type of seat-action closet very seldom placed in private houses, is that with closed metal tank, as represented in Fig. 43. Depressing the seat opens a valve in the supply, and the water passes up through a flush pipe into a closed tank. The air in the tank is compressed until the air-pressure counterbalances that of the water. When the seat is released, the supply valve closes; and a valve is opened, establishing communication between the closet and the tank. The compressed air then expels the water in the tank, flushing the closet just as a large supply with corresponding pressure would do without a tank. Closed-tank closets depend on pressure. The space occupied by the air in the tank is inversely proportional to the pressure; hence, even in heavy pressure, considerable of the tank's capacity is yet occupied by air when equilibrium is established; and the less the pressure, the smaller the amount of water it is possible to get into the tank. They are therefore not fit for very light pressures, though they sometimes serve well in the basement of a building where failure would be certain on the upper floor.

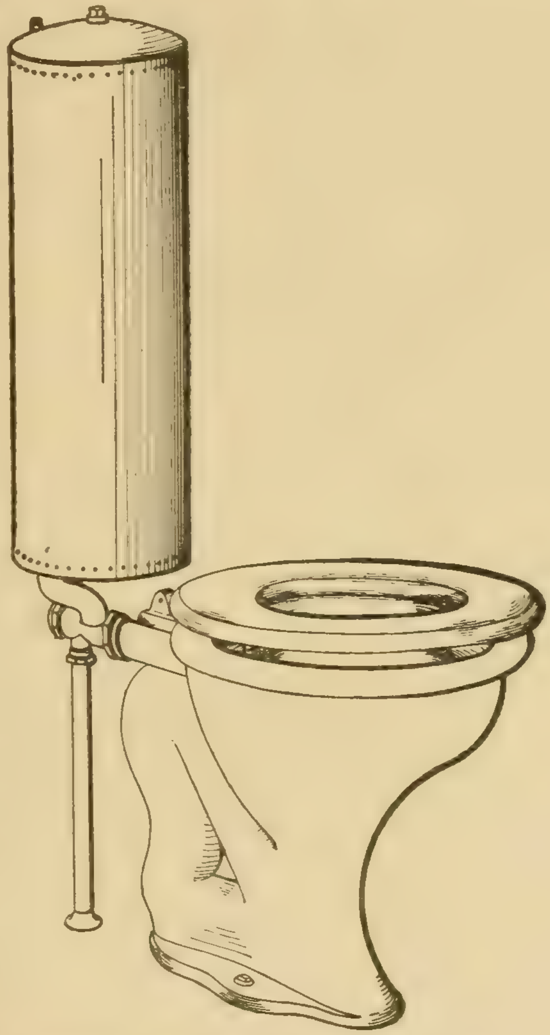


Fig. 43. Seat-Action Closet with Closed Metal Tank.

Condensation on metal tanks is annoying. Open tanks of porcelain and iron are used more or less, but sweating is hard to overcome. Zinc paint and ground cork finishes have been employed with some satisfaction; and drip-cup collars discharging into the flush just under the tank have served in this capacity, but nothing overcomes the sweating so well as a tight wood case, insulated metal cases not excepted. Some makes of the pressure-tank closet require too much weight on the seat for successful operation by a child, and children would as a rule leave the seat too soon to allow the tank to fill reasonably well. The flush pipe of pressure closets is from a few inches to four feet in length. The after-fill is accomplished by projecting the flush connection into the tank an inch or more, and drilling a $\frac{1}{4}$-inch hole or less through it near the bottom of tank. The rapid flow ceases when the water-level falls to the upper end of the inward-projecting flush connection, and the after-fill drains into and down the flush slowly.

The flush fittings of an open tank consist essentially of a valve to admit water to the flush pipe; an overflow always open to the flush pipe; and a lever and connection, with chain and pull or button, to open the flush valve. A simple example of these is the siphon gooseneck, with flush-valve disc on one end and lever connection at the other. Prongs extend below the disc to guide and keep it in place. The overflow is through the gooseneck. Lifting the gooseneck an instant permits enough water to flow down the flush to start the siphon through it when the pull is released. The tank then siphons to the lower end of the gooseneck arm.

Where shortness of flush pipe or form of closet requires a decided after-fill, this is secured by special provision in the flush fittings, or by leading some of the supply delivered by the ball cock into the overflow.

The supply fittings of a closet tank consist merely of a ball cock of suitable form. For light pressure, simple leverage suffices. For heavy pressure, the inlet in the valve would have to be too small, or the ball too large and stem too long, for a small tank, if simple leverage were employed. Therefore compound-leverage cocks are usually substituted where the pressure contended with is over 30 pounds. There are ball cocks made in which the buoyancy of the ball merely operates a small secondary valve in a way to establish the initial pressure over a disc of larger upper surface than that of the under side which covers the main water inlet of the cock. The disc is thus effectually seated, regardless of the pressure; and a 4-inch ball may be arranged to close almost any size valve against any pressure.

When the cock is attached through the bottom of the tank, no precaution against sound is necessary. When the cock is fitted in high up, a pipe from the delivery is extended to near the bottom of tank for the purpose of muffling the sound of the water as it fills the tank. An unmuffled delivery and a high-tank flush make considerable noise when the closet is flushed, and are suggestive and very embarrassing to sensitive people. Silent action is therefore the goal for which many strive. Silence at the expense of thoroughly washing the closet surfaces and flushing out the contents, is not desirable; some noise is necessary to the rapidity of action essential to thorough scouring and evacuation.

Tanks requiring the flush valve to be held off the seat during the entire flush, are now no longer installed. Perfect silence in the flush pipe of a high-tank closet has been obtained by a type of flush fittings that permits the pipe to hang full of water. The flush valve being opened, water begins to flow into the closet immediately. When the valve closes, no air having access at the upper end of the flush, the pipe remains filled. The flush valve of such a closet must close absolutely water-tight to prevent continual dribbling into the bowl.

Of late years, direct-flushing valves of many forms have been a feature of water-closet design. These valves make the individual closet tank unnecessary. Direct-flushing closets, a type of which is shown in Fig. 44, have the same advantage as the low tank in the matter of being placed where high closets cannot conveniently be arranged. A check to their more general adoption has been the lack of large supplies in residences and other buildings.

The possibility that the house system of water supply may be contaminated from the water-closet if the water supply is directly connected to the water-closet fixture, should not be overlooked. Although this contamination is more likely to take place in the operation of the older types of closets, such as the pan closet and the plunger type, it is not of rare occurrence in connection with later types, especially the so-called *frost-proof* fixture. If the pressure is materially lowered in the street main by accident or otherwise, it sometimes happens that water may be drawn back into the house system by siphonage from a water-closet or like fixture, thus of course incurring the possibility that germs of disease may be brought into the water supply used for domestic purposes. The use of a tank into which the water is first drawn, obviates this danger.

The ordinary dwelling or storehouse supply can be made to operate successfully by placing an accumulating chamber on the branch to the closet, and having a check-valve on the street side of it, so that the water cannot flow back when the pressure falls as a result of drawing at other points. In such cases the pipe between the accumulator and the closet must be the usual $1\frac{1}{2}$-inch size. Closets thus fitted are really only pressure-tank closets with the flush controlled by a direct-flushing valve to be operated at will instead of automatically by seat-action.

In all tank installations, the direct method is easily employed by carrying the proper size flush main directly to the closets, independently of the supply for other fixtures. This is recommended in buildings having numerous closets. One tank, with large flushing main, will serve all the closets, and thus the individual tanks and equipment are not needed. Furthermore, no trouble is then experienced in providing suitable space for the small tanks. The flushing valves may, if desired, be placed out of sight, and only the operating lever brought to view in a convenient position. A flushing valve has been made which, like the secondary-valve ball cock, works on the old Jennings diaphragm principle, using a "time" filling cup to establish the initial pressure over the diaphragm. Releasing the pressure over the diaphragm by means of the operating lever, opens the main channel and causes the closet to flush while the time chamber fills again.

In this country and most others, the height of closets has always been uniformly 16 to 17 inches to top of seat. It is claimed that this height results in an unnatural position, and individual opinions against it have been voiced from time to time with little effect. Lately, however, more earnest attention has been given the subject of height, and there has been designed a closet considerably lower than usual, with the top sloping down toward the back. This form, it is said, induces the user to assume an upright position of body, relatively more closely conforming to that of the limbs, and favoring unrestricted action of the intestines. It remains to be seen whether this form will result in any general departure from the old lines.

Closets often also serve as urinals, especially in private houses. For limited service, this is not to be considered an actual abuse of the fixture, though general use of distinct urinal fixtures is indispensable.

Range Closets. Batteries of individual closets are usual in office buildings and many other such structures; but in schools and in many public places open to all classes, ranges divided into stalls or compartments have been considered a satisfactory solution of the problem.

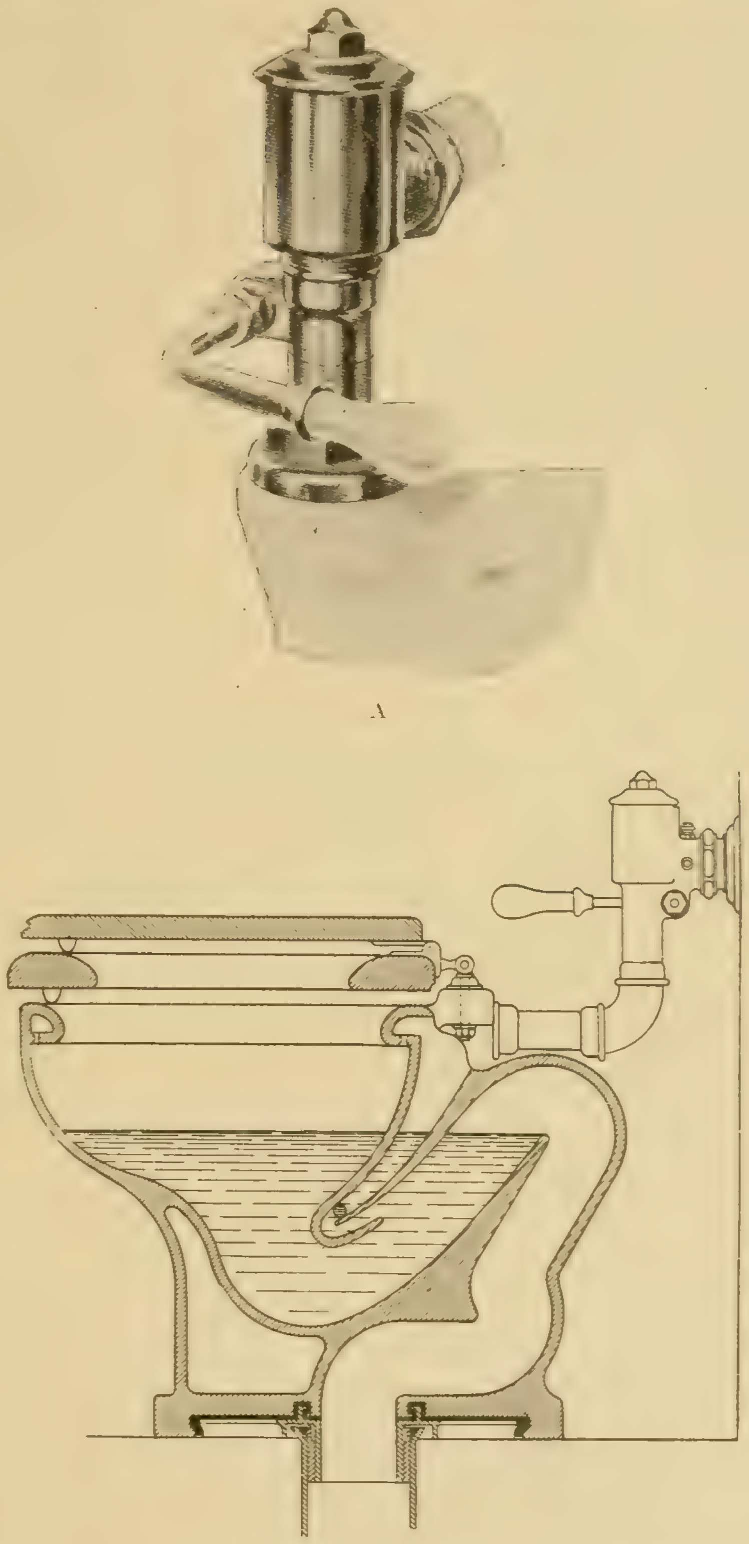


Fig. 44. Direct-Flushing Closet Dispensing with Necessity of Tank. *A* Shows Hand-Flushing Valve; *B* Complete Fixture with Sectional View of Siphon Closet.

Courtesy of the J. L. Mott Iron Works.

The objections to the range type of fixture are inherent in the design. The fouling surface of a trough fixture is much greater than that of the number of individual closets to which the fixture corresponds, and certain parts of this surface are not subject to an adequate flushing action. A certain portion of the surface, much larger relatively than that in individual fixtures, is exposed to spattering with the filth, and is alternately wet and dry. It is also true that the method of applying the water for scouring purposes is much less satisfactory than with single closets. A further objection to the range fixture is that in general its material is less desirable for the purpose than the earthenware or porcelain used for closets. On account of these deficiencies, for some ten years past, individual closets have been used in public schools in certain cities which have given the most attention to this branch of sanitation, and their use is being extended.

Range closets have automatic flushing tanks acting at any required interval between flushes. The tanks are, as a rule, without moving parts, and give good service without much attention after the supply is once set to flush at the interval desired. Whether the users of a closet are indifferent or irresponsible, does not change the result of abuse; and the range type of closet overcomes many annoyances attending the use of ordinary individual closets in unsuitable places—institutions for the insane and feeble-minded, for example. Ranges, like seat-action closets, are not dependent on the user, who may forget to pull a chain or push a button and thereby leave the closet foul.

Various forms of ranges are now operated on the siphon eduction principle. Siphonic eduction is accomplished in three ways—first, by the double trap and air-pipe to the tank indicated by the sectional view, Fig. 45, and operating exactly like the individual pneumatic closet already described; second, by a siphon outlet-end in which the water falls over a central weir that maintains the proper depth of water until the flush begins, and causes siphonage by breaking up and filling the channel as it passes through a constricted bend below. The latter method is shown in section in Fig. 46. Still another type of range is made to siphon by jet-action, just as the individual jet-siphon closet does, the trap providing a retaining weir which holds the water at the proper level in the range between flushes.

There are wash-out ranges with sloping weirs at the outlet to retain enough water to keep soil from sticking. These are open troughs, and the plumber provides the trap. Some siphon ranges are of the open-trough pattern, but the trap or the siphon outlet is a part of the fixture. All open-trough ranges can be supplied with a ventilating section from which a large vent pipe may be carried to a stack in which a draft is insured by a hot flue or some other means. Such ventilation changes the air in the room; and by having lids to all the seats, odors from the entire trough may be uniformly removed by leaving up one lid only, at the end opposite the vent pipe. Some forms, having individual flushing-rim bowls cast integral with the section, are supplied by one general flush pipe, as indicated by the plan and elevation shown in Fig. 47. In these, each bowl is separately water-sealed, as the normal water-level is above the general conduit into which the bowls discharge.

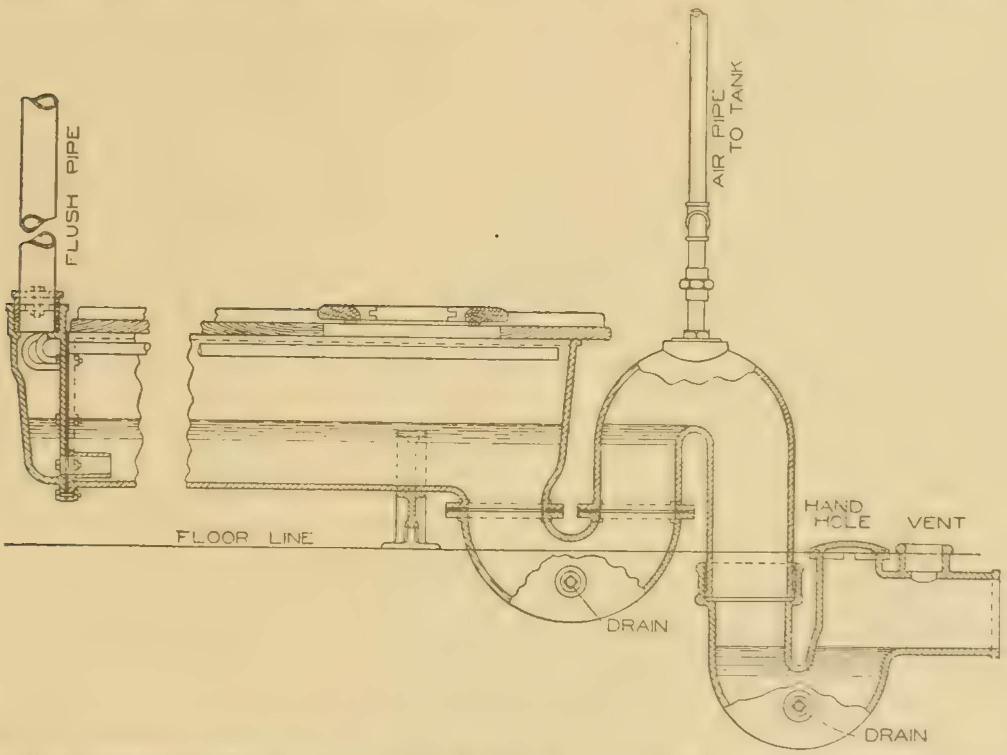


Fig. 45. Section of Range Closet, with Double Trap and with Air-Pipe to Tank to Cause Siphonic Eduction.

Other forms, which receive the entire flush at one end, are water-sealed between the seat holes. The seat-openings, instead of converging like flushing-rim bowls, diverge downward, so that, as the water-level recedes in the sections during flushing, soil falls away from the surface by gravity instead of grinding against it. Therefore, so far as cleanliness is concerned, the type with diverging surfaces but without the scouring effect of flowing water in the openings is, in operation, the practical equivalent of the flushing-rim type with converging surfaces. The open-trough ranges, including the jet-siphon type, have perforated wash-down pipes along the sides and ends, which, however, have little value. The open troughs are made in cast sections as long as convenient, joined by flanges with rubber gaskets and bolts. Suitable feet or chairs for supports are furnished with these fixtures.

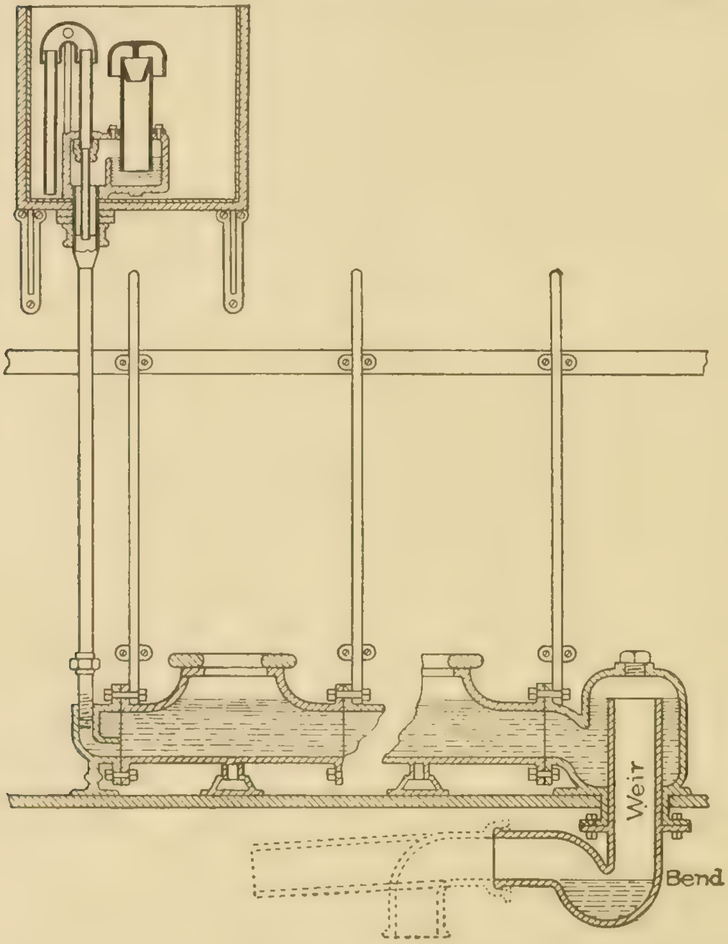


Fig. 46. Section of Range Closet, with Siphon-Outlet End.

Cast partitions, partitions and backs, and full compartment partitions, with slat doors and indicators, are furnished to order in any style or combination desired. For example, the range for a schoolroom may consist altogether of 24-inch sections or divisions, except one intended for the teachers' use made 30 inches and fitted with door and full-length partitions to give a thoroughly private compartment. Ranges are usually made of cast iron, and almost invariably finished with enameled interior and painted exterior. Bowl or section ventilation is provided for where possible. Wood seats and covers are generally used; but enameled-iron top frames with hinged seats and covers, and rigid enameled seats, are also made.

The lower trap of a double-trap range must be ventilated. All soil-pipe stacks into which ranges discharge, and fixtures connected to them, must be well protected against siphonage, because the volume of water discharged at one time by a range is sufficient to siphon traps that would retain their seals under most other conditions.

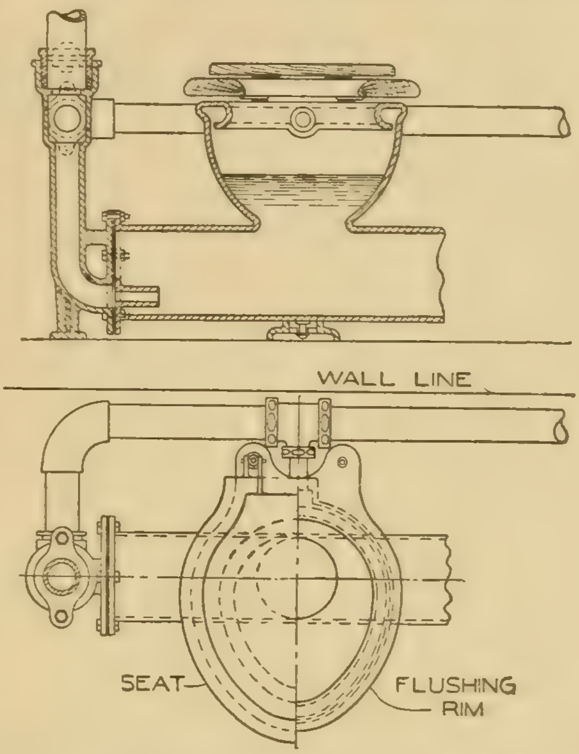


Fig. 47. Sectional Elevation and Plan of Range Closet Seat with Flushing-Rim Bowl Supplied from General Flush-Pipe.

Urinals. Sectional urinals are made of the same materials and finish, and with much the same types of design, as range closets. They are generally installed in the same classes of buildings as range closets; but such urinals will often be found in the same toilet-room with individual closets. Roll-rim enameled troughs, with back and with simple perforated wash-down flush pipes on the back, are available.

Single urinals are usually of porcelain, although some have been made of iron. The common types are plain or lipped, made in flat-back and corner designs. Flat-back types of both designs are shown in Fig. 48. All have flushing rims. Direct-flushing valves of the same type as used on closets, adapted to the purpose,

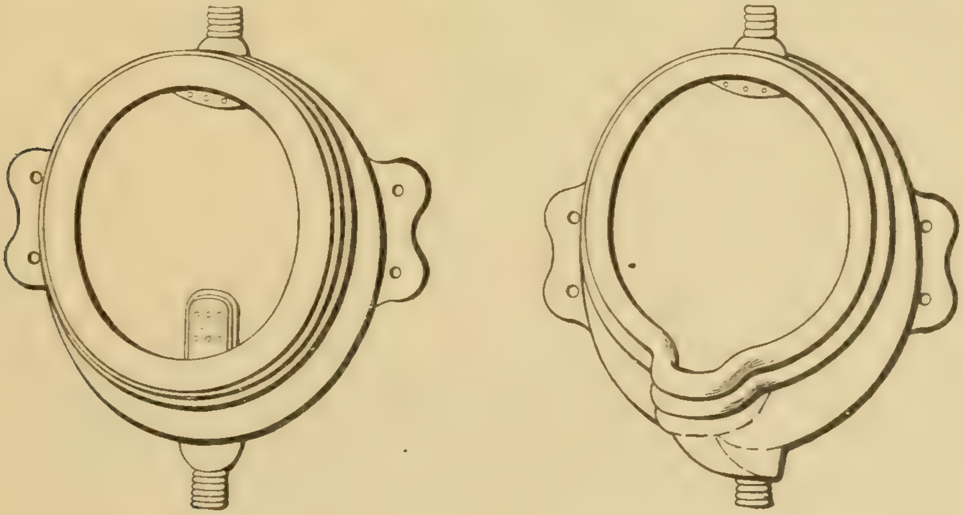


Fig. 48. Flat-Back Types of Single Urinals.

and cocks of various types, are the means of flushing generally provided for a single urinal. When two or more are placed in one toilet-room, an automatic tank with branched flush pipe is employed. These tanks are of greater variety than those used with range closets. The tilting bucket, pivoted within a tank case, which empties itself periodically by means of the flow of water changing the center of gravity to the unsupported side and tipping it just before it overflows, is a familiar type of automatic urinal-flushing tank. The standard tank with immovable parts, which siphons automatically, is also prevalent. Examples of these types are illustrated in section in Fig. 49.

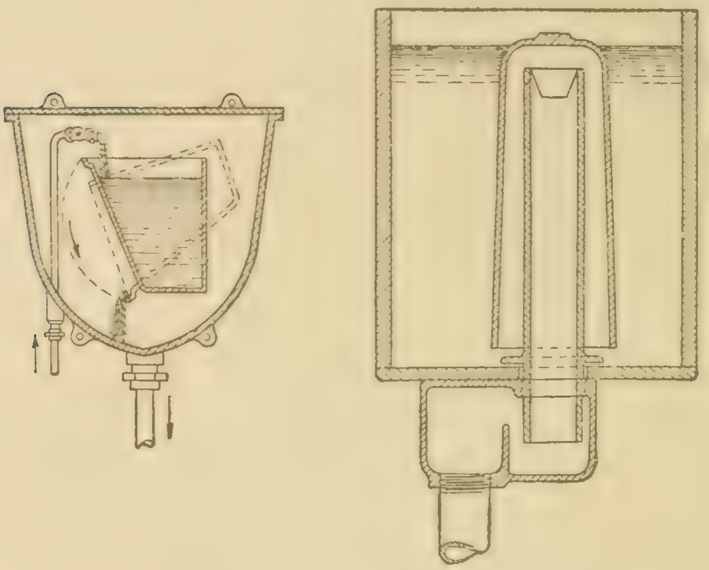


Fig. 49. Automatic Urinal-Flushing Tanks. Tilting-Bucket Type at Left; Self-Siphoning at Right.

Another design consists of a tank with common siphon, fitted with a ball cock which *opens*, instead of closing, as the water in the tank lifts the ball. The interval between flushes is governed by a small bibb cock, which may be turned on more or less so as to take greater or less length of time for the water in the tank to reach the ball. When water begins to lift the ball, the ball cock also admits water. From this point the tank fills

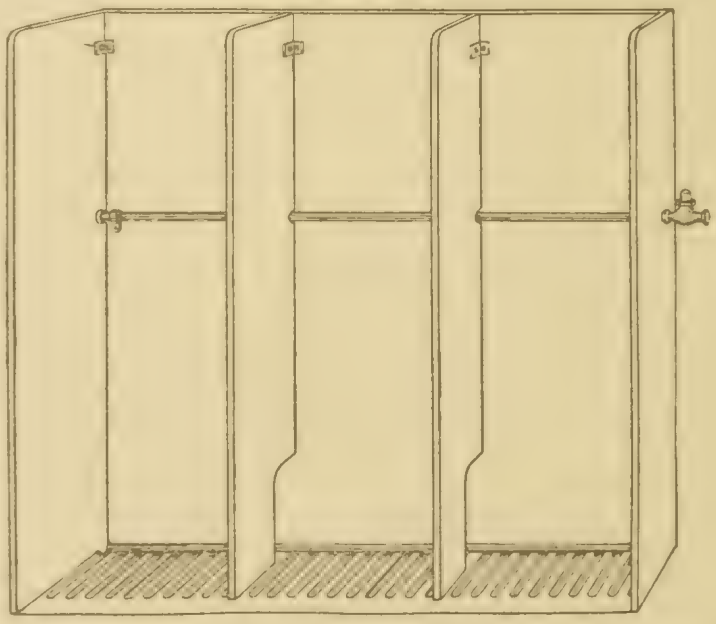


Fig. 50. Urinal Stalls of Slate or Marble, Flushed by Perforated Pipe, with Channeled and Guttered Floor.

rapidly. The higher the ball is lifted, the faster the tank fills, so that by the time the water-level reaches a point where water begins to flow over the neck of the siphon, it is coming into the tank rapidly enough to more than keep pace with the overflow necessary to start the siphon. True siphonage, however, empties the tank much faster than the supply can fill it; and the tank is soon empty, leaving the small bibb cock to admit water again slowly to where this action can be repeated.

Individual urinals which siphon by admitting additional water to that which normally stands in the fixture, and various other types, will be best understood from a study of dealers' catalogues. In good work, marble backs and partitions usually enclose the urinals on three sides. Marble and slate stalls of various construction, with channeled and guttered floor, as shown in Fig. 50, all washed by perforated pipes fixed along the surfaces, are frequently used in lieu of specific urinal fixtures. A thick base of slab material is sometimes used, the gutter and drain-hole being cut in it. Cast-iron gutters, galvanized or enameled, with an outlet-end adapted to a soil-pipe connection, are supplied by the makers.

In describing the fixtures and trimmings that have been noticed, only salient features of form and principles of design have been considered. Sufficient guidance to insure intelligent comparison of merits and skilful discrimination in selection, has been given. Catalogue detail and illustration, and a view of the actual goods described therein, should, with what has now been given, insure the fullest understanding of the fixture branch of Plumbing.

HOUSE WATER SUPPLY

While the plumber is apt to give more attention to supply pipe, and to methods of installing it in buildings to secure specific service, *water supply* embraces also, in its broadest sense, the source and quality of water and the means of conveying it to the building. Plumbers generally have little dealing with water supply outside of the house walls. Custom has fixed certain arbitrary sizes in ordinary work, to such a degree that the average plumber has generally ignored information on the flow of water through pipes. Indeed, he is so rarely in actual need of this knowledge, that it appears a burden to acquire and to fix permanently in his mind the simplest formula bearing on the subject. Enough information to determine approximate deliveries and point the road to further research, will not be out of place in behalf of those who may need simple directions.

The laws of gravity are the basis for the science of hydraulics, of which a prime factor of every problem is *velocity*. There is no exception to the rule that all bodies falling freely, descend at the same rate—in round numbers, 16 feet for the first second, at the end of which the acquired velocity is one of 32 feet a second. This is the basis on which are formulated the laws of falling bodies, which, exhibiting what is known as *velocity of efflux*, together with loss by friction, must be considered when calculating the flow of water.

There are three kinds of velocity—*uniform*, *accelerated*, and *retarded*. It is the last, and its cause, friction, that plumbers should be most interested in, as velocities calculated merely from the laws of falling bodies do not take account of friction, change of course, etc., which must be allowed for as causes diminishing the delivery of water through pipes. Briefly stated, the mysterious-looking Torricellian formula $\sqrt{2gh} = V$, means only that velocity is found by extracting the square root of the product of the head multiplied by 2×32, g standing for the force of gravity, and h for the height. For example, a stream filling a 1-inch pipe, with 25 feet head of water, would have a velocity calculated thus: $2 \times 32 \times 25 = 1{,}600$; and the square root of $1{,}600 = 40 =$ Velocity, friction not considered.

The shape of the orifice through which water enters a pipe, has much to do with the amount of water that will enter it. Friction against the sides of the pipe, and change of direction due to bends and connections, occasion great variation from the theoretical flow. Not only is the character of the pipe surface and fittings to be considered as initial causes varying the delivery, but velocity, the all-important factor, must be reckoned with in every instance. With a velocity of 10 feet per second in a pipe of comparatively smooth interior surface, the friction loss in pounds on one square foot of surface will be about ½ pound. If this velocity is increased or diminished, the factor of friction will vary accordingly, always in proportion to the square of the velocity. Suppose the velocity to be 20 feet instead of 10 feet per second; we then have, 10 squared equals 100, and 20 squared equals 400. The square of these velocities is as 1 to 4, and as we assign a ½-pound loss to ten feet velocity per second, on a stated amount of surface, the friction due to doubling the velocity should be four times a ½ pound = 2 pounds, showing that doubling the velocity increases the friction four-fold; trebling it increases friction nine-fold, etc.

A column of water weighs .43 pound per square inch of base, per vertical foot. Therefore a vertical pipe 100 feet high, with 1-inch sectional area, filled with water, would contain 43 pounds, and a gauge at the bottom would show 43 pounds pressure. If the pipe were only ¼ inch, or were 40 inches in diameter, the gauge would show the same pressure for the same vertical height—namely, .43 pound per square inch per vertical foot. A head of water expressed in feet, may be changed to pounds by multiplying the feet of head by .43. Pressure is made to read in feet of head by multiplying pressure per square inch by 2.3. A *head of water* is the number of vertical feet from level of source of supply to center of outlet or point of delivery.

Diameter of the pipe has nothing to do with static head or pressure; but its relation to the size of the orifice from which the water is to be drawn has much to do with the amount of pressure lost by friction. If a faucet and supply pipe are of the same size, and we *double* the size of the pipe, the velocity of the water flowing through it is reduced three-fourths; and the friction is, under these conditions, but one-sixteenth what it was in the original size. Moreover, as in drawing similar amounts of water under the same head through a one-inch and a two-inch pipe, the amount of friction surface presented is twice as great in the one-inch as in the two-inch pipe, the friction in the one-inch can be shown to be 32 times as much as in the two-inch pipe.

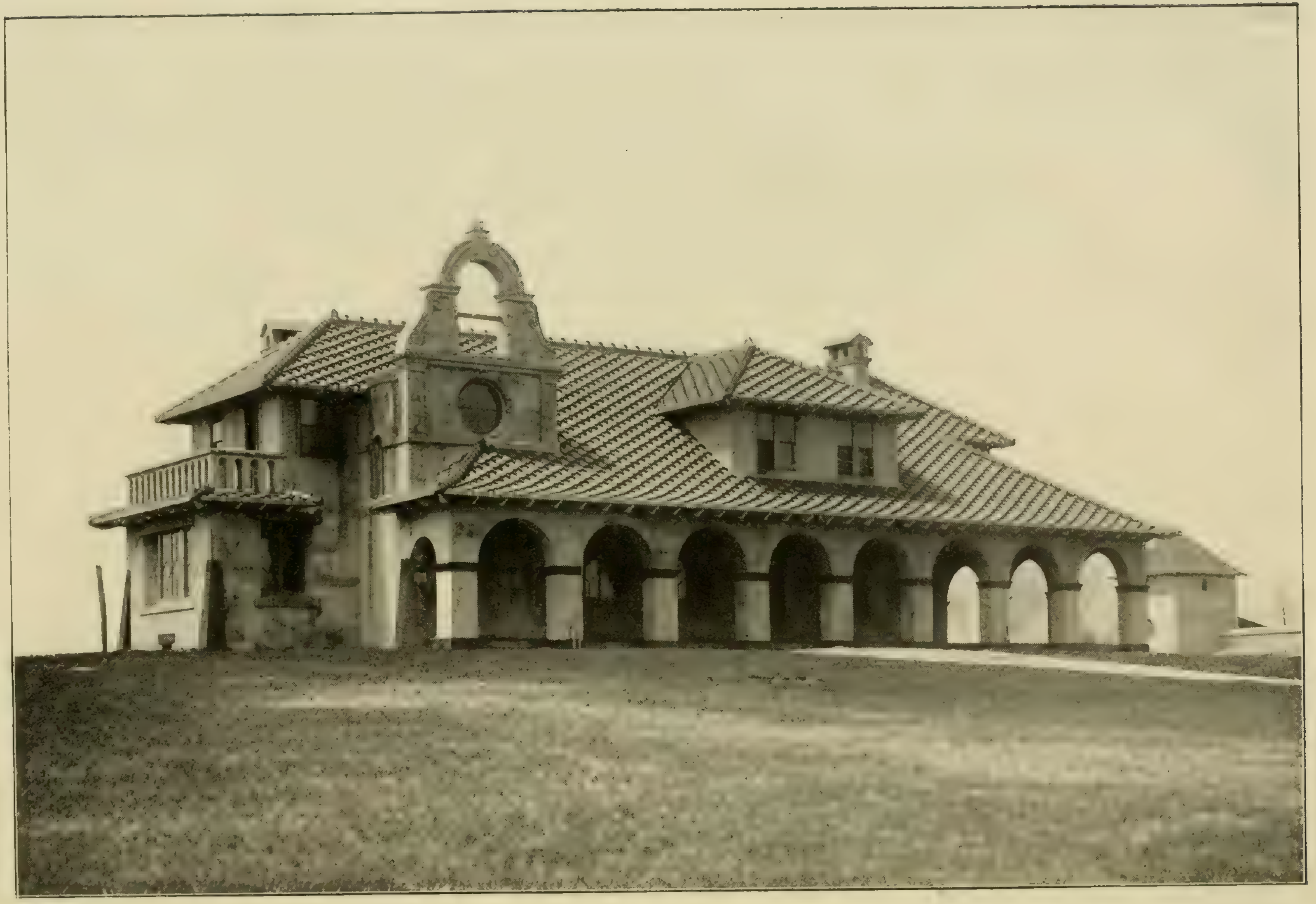
With the formula given, one can roughly approximate by finding the theoretical delivery and deducting a liberal percentage for friction, according to size, length of pipe, and head or pressure. The subject, however, is vast and tedious, introducing intricate calculations in higher mathematics when considered in detail with a view to extreme accuracy of results, and is a branch properly belonging to hydrodynamics, rather than suited to presentation at length here. Two tables are given, however, which with the rules for use, will be of value to those who fail to make further research.

Table I shows the pressure of water in pounds per square inch for elevations varying in height from 1 to 135 feet.

Table II gives the drop in pressure due to friction in pipes of different diameters for varying rates of flow. The figures given

TABLE I

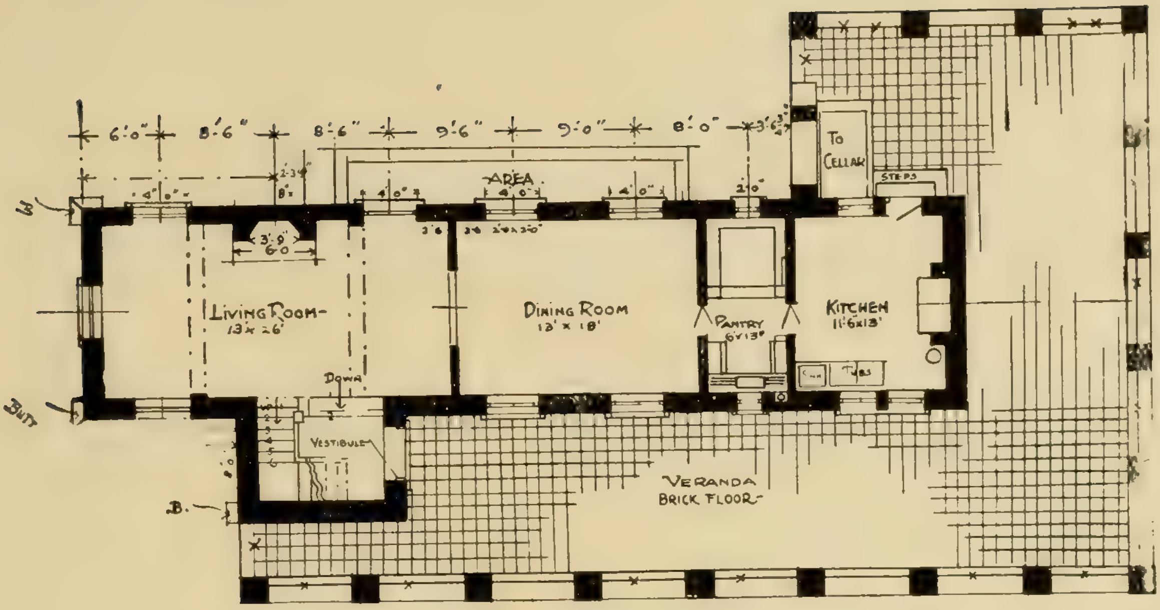
Head in feet	Pressure pounds per square inch	Head in feet	Pressure pounds per square inch	Head in feet	Pressure pounds per square inch
1	.43	46	19.92	91	39.42
2	.86	47	20.35	92	39.85
3	1.30	48	20.79	93	40.28
4	1.73	49	21.22	94	40.72
5	2.16	50	21.65	95	41.15
6	2.59	51	22.09	96	41.58
7	3.03	52	22.52	97	42.01
8	3.46	53	22.95	98	42.45
9	3.89	54	23.39	99	42.88
10	4.33	55	23.82	100	43.31
11	4.76	56	24.26	101	43.75
12	5.20	57	24.69	102	44.18
13	5.63	58	25.12	103	44.61
14	6.06	59	25.55	104	45.05
15	6.49	60	25.99	105	45.48
16	6.92	61	26.42	106	45.91
17	7.36	62	26.85	107	46.34
18	7.79	63	27.29	108	46.78
19	8.22	64	27.72	109	47.21
20	8.66	65	28.15	110	47.64
21	9.09	66	28.58	111	48.08
22	9.53	67	29.02	112	48.51
23	9.96	68	29.45	113	48.94
24	10.39	69	29.88	114	49.38
25	10.82	70	30.32	115	49.81
26	11.26	71	30.75	116	50.24
27	11.69	72	31.18	117	50.68
28	12.12	73	31.62	118	51.11
29	12.55	74	32.05	119	51.54
30	12.99	75	32.48	120	51.98
31	13.42	76	32.92	121	52.41
32	13.86	77	33.35	122	52.84
33	14.29	78	33.78	123	53.28
34	14.72	79	34.21	124	53.71
35	15.16	80	34.65	125	54.15
36	15.59	81	35.08	126	54.58
37	16.02	82	35.52	127	55.01
38	16.45	83	35.95	128	55.44
39	16.89	84	36.39	129	55.88
40	17.32	85	36.82	130	56.31
41	17.75	86	37.25	131	56.74
42	18.19	87	37.68	132	57.18
43	18.62	88	38.12	133	57.61
44	19.05	89	38.55	134	58.04
45	19.49	90	38.98	135	58.48



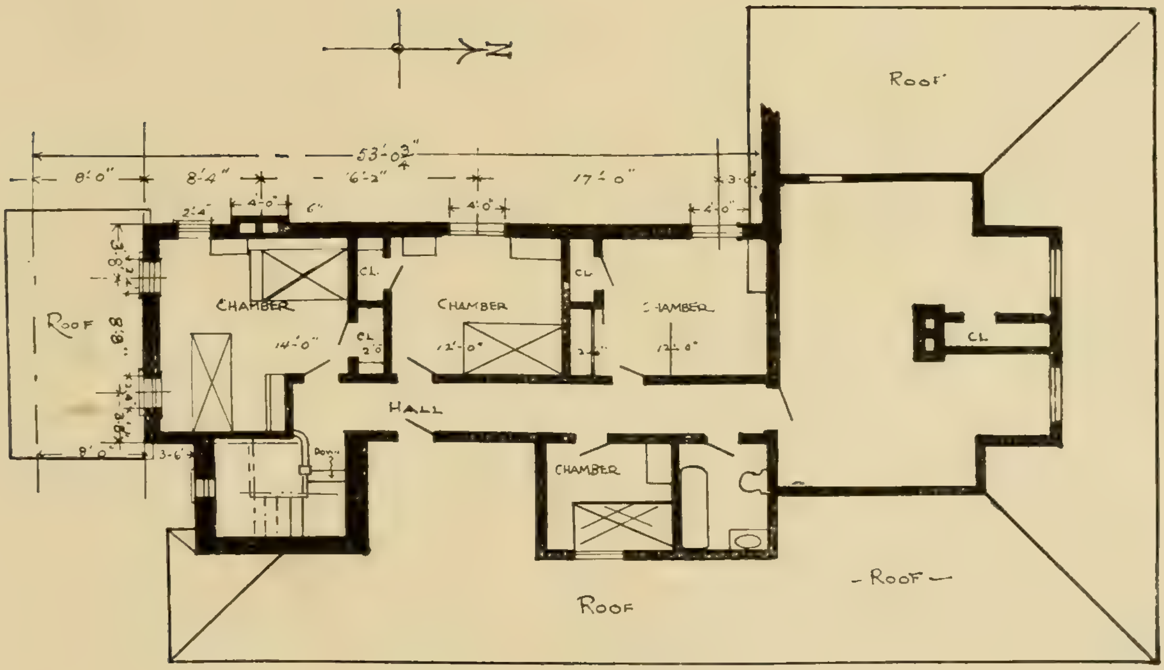
RESIDENCE OF MR. W. H. KNIGHT, BRISTOL, R. I.

Parkhurst & Kissam, Architects

Built of Solid Reinforced Concrete. Plans Shown on Opposite Page.



FIRST FLOOR PLAN



SECOND FLOOR PLAN

PLANS OF RESIDENCE OF MR. W. H. KNIGHT, BRISTOL, R. I.

Parkhurst & Kissam, Architects

Exterior View Shown on Opposite Page.

are for pipes 100 feet in height. The frictional resistance in smooth pipes having a constant flow of water through them is proportional to the length of pipe. That is, if the friction causes a drop in pressure of 4.07 pounds per square inch in a 1¼-inch pipe 100 feet long, which is discharging 20 gallons per minute, it will cause a drop of 4.07 × 2 = 8.14 pounds in a pipe 200 feet long; or 4.07 ÷ 2 = 2.03 pounds in a pipe 50 feet long, acting under the same conditions. The factors given in the table are for pipes of smooth interior, like lead, brass, or wrought iron.

TABLE II.

Gallons discharged per minute.	½ in.		¾ in.		1 in.		1¼ in.		1½ in.		2 in.		2½ in.		3 in.	
	Velocity in feet per second.	Friction loss in pounds.	Velocity in feet per second.	Friction loss in pounds.	Velocity in feet per second.	Friction loss in pounds.	Velocity in feet per second.	Friction loss in pounds.	Velocity in feet per second.	Friction loss in pounds.	Velocity in feet per second.	Friction loss in pounds.	Velocity in feet per second.	Friction loss in pounds.	Velocity in feet per second.	Friction loss in pounds.
5	8.17	21.6	3.63	3.3	2.04	.84	1.31	.31	.91	.12						
10	16.3	96.0	7.25	13.0	4.08	3.16	2.61	1.05	1.82	.47	1.02	.12				
15			10.9	28.7	6.13	6.98	3.92	2.38	2.73	.97	1.53	.27				
20			14.5	50.4	8.17	12.3	5.22	4.07	3.63	1.66	2.04	.42				
25			18.1	78.0	10.2	19.0	6.53	6.10	4.54	2.62	2.55	.67	1.63	.21	1.13	.10
30					12.3	27.5	7.84	9.15	5.45	3.75	3.06	.91				
35					14.3	37.0	9.14	12.04	6.36	5.05	3.57	1.25				
40					16.3	48.0	10.4	16.10	7.26	6.52	4.09	1.60				
45							11.7	20.2	8.17	8.15	4.60	2.02				
50							13.1	24.9	9.08	10.0	5.11	2.44	3.26	.81	2.27	.35
75							19.6	56.1	13.6	22.4	7.66	5.52	4.90	1.80	3.40	.71
100									18.2	39.0	10.2	9.46	6.53	3.20	4.54	1.31
125											12.8	14.9	8.16	4.89	5.67	1.99
150											15.3	21.2	9.80	7.00	6.81	2.85
175											17.1	28.1	11.4	9.46	7.94	3.85
200											20.4	37.5	13.1	12.47	9.08	5.02

Examples.—A 1¼-inch pipe 100 feet long connected with a cistern is to discharge 35 gallons per minute. At what elevation above the end of the pipe must the surface of the water in the cistern be to produce this flow?

In Table II we find the friction loss for a 1½-inch pipe discharging 35 gallons per minute to be 5.05 pounds. In Table I we find a pressure of 5.2 pounds corresponds to a head of 12 feet, which is approximately the elevation required.

How many gallons will be discharged through a 2-inch pipe 100 feet long where the inlet is 22 feet above the outlet? In Table I we find a head of 22 feet corresponds to a pressure of 9.53 pounds. Then, looking in Table II, we find in the column of Friction Loss for a 2-inch pipe that a pressure of 9.46 corresponds to a discharge of 100 gallons per minute.

Tables I and II are commonly used together in examples.

A house requiring a maximum of 10 gallons of water per minute is to be supplied from a spring which is located 600 feet distant, and at an elevation of 50 feet above the point of discharge. What size of pipe will be required? From Table I we find an elevation or head of 50 feet will produce a pressure of 21.65 pounds per square inch. Then if the length of the pipe were only 100 feet, we should have a pressure of 21.65 pounds available to overcome the friction in the pipe, and could follow along the line corresponding to 10 gallons in Table II until we came to the friction loss corresponding most nearly to 21.65, and take the size of pipe corresponding. But as the length of the pipe is 600 feet, the friction loss will be six times that given in Table II for given sizes of pipe and rates of flow; hence we must divide 21.65 by 6 to obtain the available head to overcome friction, and look for this quantity in the table, 21.65 ÷ 6 = 3.61, and Table II shows us that a 1-inch pipe will discharge 10 gallons per minute with a friction loss of 3.16 pounds, and this is the size we should use.

In calculating the contents of pipes, cylinders, and cisterns, where it is usual to correct the area found as a result of squaring the diameter by multiplying by .7854, before dividing by 231 for U. S. gallons, multiplication by the decimal may be omitted, and dividing by 294 instead of 231 will then give the same result.

EXAMPLES FOR PRACTICE

1. What size pipe will be required to discharge 40 gallons per minute, a distance of 50 feet, with a pressure head of 19 feet?

Ans. 1¼-inch.

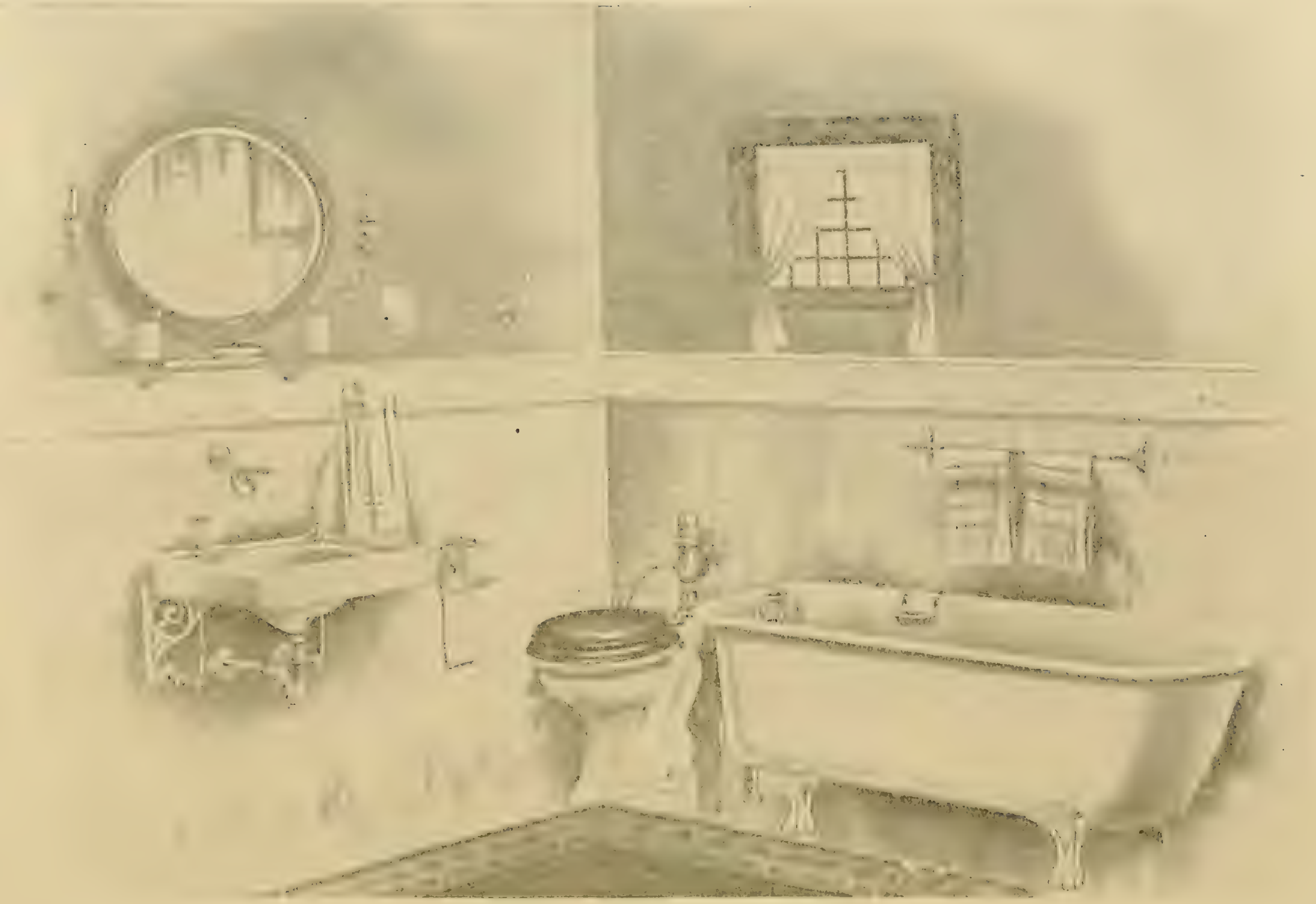
2. What head will be required to discharge 100 gallons per minute through a $2\frac{1}{2}$-inch pipe 700 feet long?

Ans. 52 feet.

TYPES OF WATER SUPPLY

There are various ways in which it may be necessary to obtain the water supply for a building. The usual course in cities and towns is to employ the Municipal Water Works service. This, of course, settles the supply feature, and the plumber simply provides the house and yard pipe, $\frac{5}{8}$-inch or larger main, according to the character of the work. If of lead, the pipe must be of strength according with the pressure. Any of the light-weight grades of lead supply will stand 1,000 pounds per square inch for a short time; and the usual strength used on 50 to 80-pound pipe will not burst under 1,400 to 1,600 pounds when new and unstrained. Under constant pressure, the enormous strain possible from water-hammer, and general deterioration from use, make it advisable to employ pipe which, when new, is 20 times as strong as that necessary to contain the pressure. No attention is necessary as to the strength of zinc-coated or tin-coated iron pipe; it will stand any pressure ordinarily encountered.

The two general methods of supplying buildings with water are: (1) the *direct* system; and (2) the *indirect* or *tank* system. The direct method, generally employed in cities, places each fixture connected with the supply under the same pressure as the street main, unless a reducing valve is introduced, thus often subjecting the work to needless high pressure and always to the widely varying conditions and quality of service incidental to such use. In the direct system it is good practice, where at all practicable, to pipe and fit the work generally for pressure not exceeding 50 pounds per square inch, and then use a reducing valve to maintain such pressure as is required.



REPRESENTATIVE TYPE OF MODERN AMERICAN BATHROOM

PLUMBING

PART II

PUMPS

A common *suction pump*, shown in Fig. 65, is the type generally used in cisterns or other very short lifts. *B* is the plunger; *C*, the bottom valve; and *D*, the plunger valve. When the plunger is drawn up, a vacuum is formed in the cylinder, and water flows in through *C* to fill it. When the plunger is forced down, valve *D* opens and allows the water to flow through the plunger while *C* remains closed. Water is thus raised by the plunger at each stroke and flows from the spout in an intermittent stream. The atmospheric limit is indicated in the engraving; but, as before stated, the practical lift is taken at 20 feet or less in pumps having the plunger valve at the ground level. The plunger in this kind of pump is made to trip the bottom valve and drain the pump at will, without a waste-hole or special cock, by merely lifting the handle as high as possible.

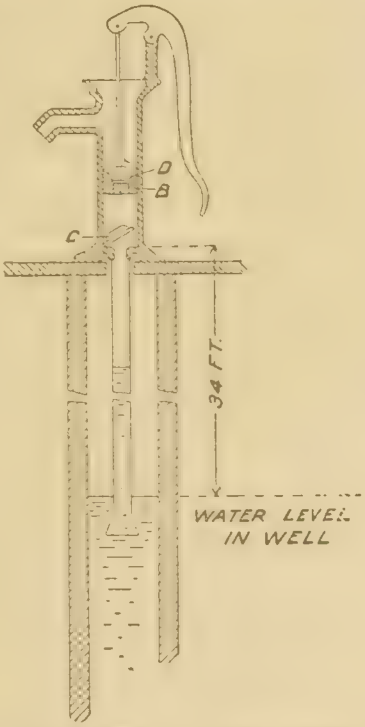


Fig. 65. Common Type of Suction Pump for Short Lifts.

When the surface of the water is a greater distance below the pump stock than ordinary suction can reach effectively, the cylinder and its working parts must be placed within the limits of lift by suction. This form is termed a *lift pump*, one type of which is shown in Fig. 66. This particular form is confined to ordinary open shallow wells or deep cisterns. It drains automatically through a waste-hole always open below frost line, located in the stock above the working barrel. There is no limit except the strength of the parts, to which a good lift pump will not bring water if the cylinder is near enough to the water and the pump in good order.

The forcing feature of a pump, making it a *lift and force pump*, is secured by working the rod of an ordinary lift pump through a stuffing box, and adding an air-chamber to take care of the surplus water pumped on the up-stroke and to expel it while the plunger is being lowered. All the water is pumped on the up-stroke of the plunger, in these pumps; and the expulsion of the surplus through the constricted spout, giving the familiar steady stream, is due to the action of the air compressed in the chamber.

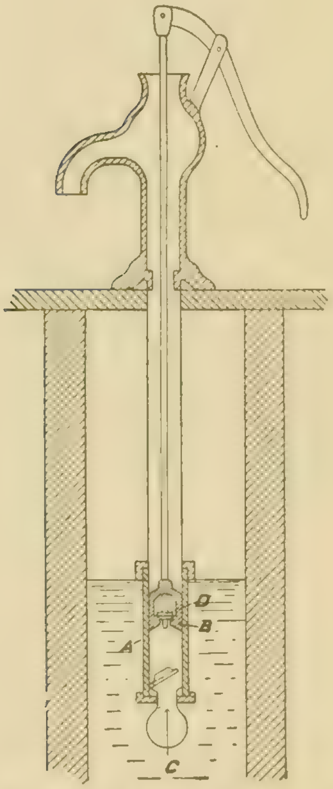


Fig. 66. Type of Lift Pump Adapted to Long Lifts.

Double-acting lift and force pumps draw water by suction on both strokes, and actually expel it by force into the discharge, the suction and force being alternate in the same cylinder on both sides of a solid plunger. The air-chamber in these cushions the delivery.

It may be stated here that hot water cannot be lifted by suction, because the boiling point of water depends upon the pressure on it. Therefore, any endeavor to create a vacuum with a pump results in vapor rising so freely as to prevent accomplishing appreciable results. Warm water can be forced by having the pump below the source, and practically allowing the water to flow into the pump by gravity.

In wells, whether driven, tubular, or open, it is advisable to have the cylinder very near the bottom. The pump standard, for hand use, should be strong, well-made, of 10-inch stroke, with rocking fulcrum, and with rod guided in perfect alignment; the handle leverage at least 6 to 1; lift pipe not less than 2 inches; rod, hollow, galvanized or wood; cylinder, at least twice the length of stroke, brass-lined, and not larger in diameter than the lift pipe—the whole being such that all valves can be withdrawn through the pipe and standard for repair or renewal without disturbing either standard body or pipe. A drain valve to empty standard and pipe below freezing point, is essential. A pump outfit of this character, to deliver water at the ground level, will require at the handle grip, 6 to 8 pounds force on

40-foot, 10 to 12 pounds on 50-foot, and 14 to 16 pounds on 60-foot wells. The lift pipe (above cylinder) should not be plain iron pipe. Polished iron cylinders ought not to be used, even though they are to be always submerged; incrustation will make it difficult to withdraw the cup-leathers—to say nothing of other objections.

The trouble with cylinders of larger diameter than the lift pipe, is the time and expense of withdrawing pipe and standard for repairs; and, of course, the power to pump with them equals the total lift *multiplied by* the sectional area of the cylinder in inches.

The importance of cylinder diameter will be better understood by comparison. A total lift of 100 feet, with cylinder 2 inches in diameter, gives 135 pounds, which, with the handle leverage at 6 to 1, will be lifted with from 22 to 25 pounds' force according to kind of rod, tightness of stuffing box, size of lift pipe, etc. With the same outfit and conditions, merely substitute a cylinder of 4 inches' diameter, and 540 pounds will then require to be lifted, which, with the same ratio of leverage, calls for over 90 pounds' force on the handle to lift the water. Then, if the lift pipe is materially smaller than the cylinder, the increase in velocity, when the cylinder water enters the lift pipe calls for an additional force that would astonish one. This should make it plain why so many pump standards are wrecked, bolts worn off, holes worn oblong, handles broken, cylinders continually needing new valves, and owners disgusted; it is all due to the lack of proper proportion of parts, and the enormous amount of needless work thus occasioned.

Total lift is the distance from the level of the source pumped from, to the point of discharge. This includes height to elevated tank, if there be one, and the distance from cylinder to water, if the cylinder is above the water; yet many mechanics are inclined to ignore the latter on the ground that the atmosphere lifts the water to the cylinder. It does, in fact; but the power of the vacuum which permits the atmosphere to lift the water, is as great as the weight of water so lifted, and the vacuum itself is produced and maintained by the energy of the person pumping.

The pump being outside for the purpose of sprinkling, filling vessels, etc., need not interfere with employing it to deliver water underground to the house and up to elevated tank. A cock-spout, a packed stuffing box, and a line of pipe below freezing from lift pipe to tank, are the essentials. Delivery to tank should be made over top of tank; and the line should have a cock and drain so that the tank pipe can be emptied when desired, and so that full force for sprinkling can be had by cutting off the tank line. When pumping to the tank, it is merely necessary to have the cock-spout closed and the shut-off of the tank line turned on.

The advantages of having the pump indoors, at the sink, are, (1) that water may be pumped for use directly; and (2) that it is not necessary to go outside in bad weather in order to fill the tank. The indoor pump will also conveniently serve ordinary purposes when other water fixtures of the house are out of repair.

Small *gasoline engines*, by means of pumping jacks or other methods of actuating, are often used to operate pumps. *Hot-air engines* are also frequently used for pumping purposes, such as lifting water to upper floors of buildings whenever the city pressure may be inadequate.

Windmills are a favorite means of operating outside pumps in localities where the mean wind velocity is high enough to run them economically. Light winds, and water at great depths, both contribute to increasing the size and cost of mills; while spasmodic winds require great storage capacity. If the mean wind velocity is under 7 miles per hour, mills are suited to very light pumping only. Windmills require self-priming pumps—that is, pumps that are always ready to pump water without adding priming or working rapidly to get water to the cylinder. They are also provided with governors to avoid pumping after the tank is full, and with means which high winds will automatically operate, for folding the mill out of the wind. Light winds and severe duty are counterbalanced to some extent by gearing the wheel for higher speed than is communicated to the actuating rod.

Hot-air engines can be used indoors if the supply is within the vertical distance limit and not too far from the house. If the well or source is far away, it is best to build a frost-proof house for the engine, close to the source or over the well, so that direct connection to pump-rod can be made. Hot-air engines, like gasoline engines, depend on the momentum of the speed wheel doing part of the work. In the double-cylinder type, illustrated in Fig. 67, heat from wood, coal, gas, or oil expands the air under the piston of the power side, and drives it up. At the same time, the other piston draws the air over through a heat accumulator of iron plates, where it comes in contact with a water-jacket that is filled by passing the pump discharge through it, the air thus losing some of its heat by imparting it to the water in the jacket. The same air is then forced back through the accumulator, where it reabsorbs some of the heat previously parted with, and is compressed in its partially cooled state in the bottom of the cylinder on the combustion side, where, by again absorbing heat from the fuel, the process is caused to be repeated. Thus, by alternate expansion and contraction of the air contained, the engine is operated, the water pumped for general purposes aiding by absorbing heat from the air as it passes through the jacket.

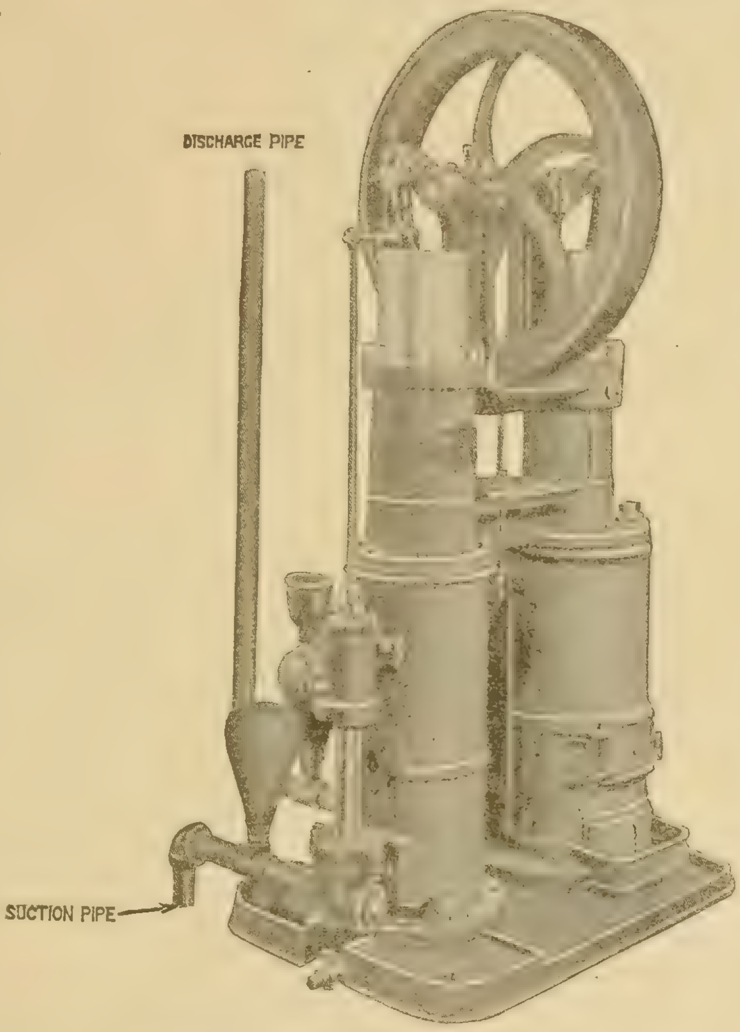


Fig. 67. Double-Cylinder Hot Air Engine for Pumping House Water Supply.

Hydraulic water-lifts have of late years been used to elevate water by water-pressure. With them various arrangements of piping to suit a wide scope of conditions are possible. If city water pressure does not reach the upper floors, the pressure on the lower floor may be employed to lift the supply for the upper floors, either for direct use from the pipe as usual, by aid of a closed accumulator, or by first delivering the water elevated into an open tank and then piping as in the ordinary tank installation. The power-water of a lift (that used to elevate with) is not wasted as in the case of a ram. The service for the low-level fixtures is simply carried through the power cylinder of the lift, and elevation takes place only during the use of faucets connected to the street pressure. The amount of water elevated is therefore governed by consumption on the lower floors; and the ratio of amount elevated to that used directly from the initial pressure, is as the capacity of the power cylinder to that of the one operated by it. An approximate estimation of the relative amounts of elevated and initial supply needed, must, on this account, be made before a lift of proper construction can be selected.

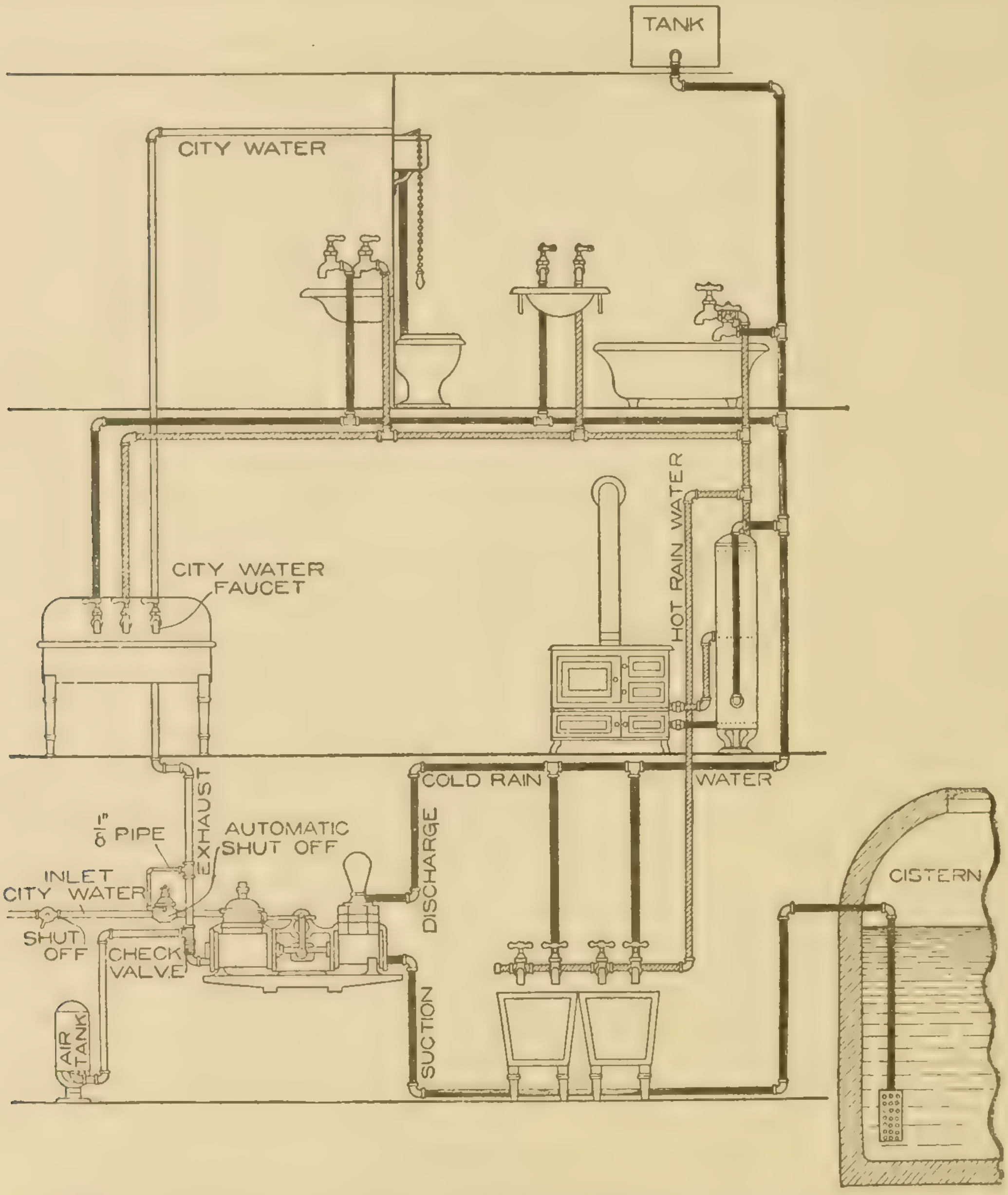


Fig. 68. Method of Using City Pressure to Pump Soft Water for House Supply.

Cistern water can also be lifted by this method to either an open or closed tank, using or wasting the power water according to circumstances. In Fig. 68 is shown a plan by which the use of hard city water, useful for some purposes, is made to pump rain water for baths, trays, etc., by means of a water lift.

Domestic supply by what is termed the *Pneumatic System,* is a feature of modern plumbing in many isolated buildings. The manner of pumping, though it may be accomplished by any of the means mentioned, is usually by hand pump. Instead of the open elevated tank supplying the fixtures by gravity, a closed tank capable of withstanding the required pressure is placed either in the cellar or in the ground. The pump is connected with the tank at the bottom, with a check-valve between the pump and tank. The house service is also taken from the bottom of the tank. Pumping the water in, crowds the air in the tank into the upper portion, so that, by the time the tank is three-quarters filled with water, there is in the neighborhood of four atmospheres' (or 45 pounds') pressure on the gauge. Part of the storage tank being occupied by air, and much of the water in it not available under the pressure thus established, higher pressures are often employed, either by pumping air in with a separate pump, or by

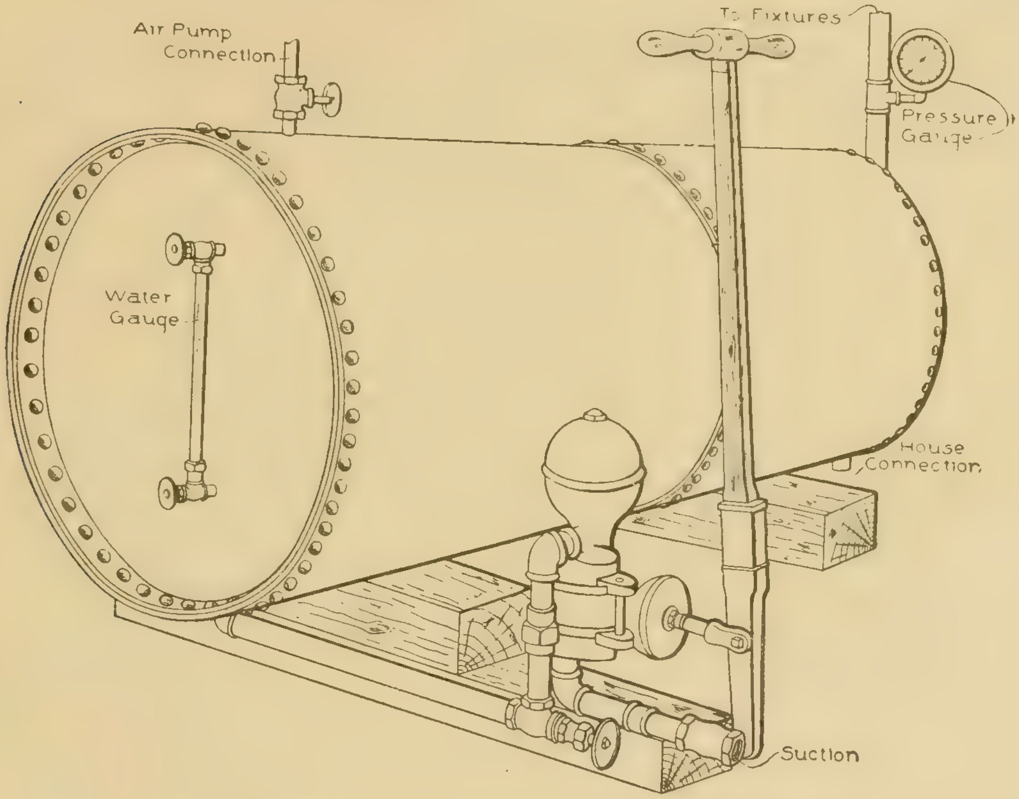


Fig. 69. Pneumatic Water-Supply Apparatus.

use of a pump delivering both water and air. The former is the more satisfactory.

A type of pneumatic service apparatus is shown in Fig. 69. The good features of these systems are that cheap and permanent support for the tank is secured; the water is kept cool in summer and free of frost in winter; and, if sufficient capacity is provided, fire-pressure for a time can be obtained. The disadvantages are that plain iron cylinders injure the water; galvanized cylinders are costly; large cylinders are hard to make and keep air-tight through the strain of transportation and installation; calking seams is expensive; a battery of small cylinders offer numerous seams and connective joints as chances for leakage, and only a fraction of the water is available under ordinary pressure; high pressure is severe on the pump and parts; and hand pumping is very laborious. Pressure higher than necessary for the purpose, is useless expense in any system.

WASHER AND HYDRANT

Assuming that a house is to be piped from city pressure, the fixtures of the yard are nearly always a street washer and yard hydrant. The principle of these is the same, but the washer is primarily intended for the attachment of hose for sprinkling purposes, while the hydrant body extends above ground so that vessels may be placed under the nozzle to have water drawn into them. The hydrant may be used to draw either with or without a hose thread on the nozzle, while no use of the street washer is possible without the thread; hence there may be a material difference in the water rates, according to the possible uses the water can be put to.

The valve of these fixtures is placed at the bottom, 2 to 5 feet below the surface, according to climate. The working parts can be withdrawn for repairs without disturbing the body. Waste-holes are open when the pressure valve is closed, so that the stem and body will empty to below the freezing point. The pressure waste-hole is not entirely closed until the hydrant or washer is approximately wide open. For this reason, turning the water only partly on when drawing or sprinkling, while it does no apparent harm, is likely to lead to trouble. If the ground is clay, it does not soak up the waste. If there is a cellar near, it will sooner or later find its way into it.

Even if care is taken in this regard and the hydrant valve fully opened when in use, there is a liability to serious dampness from the wastage into the ground of the water stored in the standpipe above the valve, which is always after a short period discharged below the ground-level through the waste-hole.

The least trouble one may expect from careless use is that the ground around the fixture will be saturated, and the body stand full of water instead of draining away; and when cold weather sets in, damage by freezing will result. The action of frozen ground in pulling up on the body of these fixtures is severe. To avoid trouble from waste water and frost, certain precautions are taken in good work. The end of an iron pipe is too rigid for direct connection. To overcome this, fittings and nipples are added so as to make the connection indirect and secure the required spring in the joints and pipe, as well as freedom from torsion. A short piece of lead pipe answers the same purpose. A cavity formed about the base of the fixture and connections, permits freedom of action and greater immunity from frost breakage.

Usually, the only positive way to insure the waste water draining away harmlessly, is to bore a dry-well under the fixture and fill it with broken rock or fragments of hard brick. This filling should extend a little above the bottom of the fixture, and should have a stout cloth folded about the body and tucked down around the brick at the edges so that the earth cannot wash in and choke the crevices of the filling.

SERVICE PIPES

The supply to the house should have a stop and waste immediately outside the wall—or, preferably, just within the wall if the cellar is frost-proof. For outside use, the iron case box is best. Combination stop and waste cocks or valves of similar principle are generally used for this and all other shut-off purposes in plumbing work, where the waste feature is permissible at all. Two separate valves or cocks serve the purpose perfectly, of course; but the waste is likely to be forgotten, thus leaving the pipe filled and subject to frost. Merely closing the stop and opening the waste will not, however, drain the pipe. It is necessary, also, to open the faucets in the house, in order that air may enter at the upper end of each line and counterbalance the atmospheric pressure at the waste so that the water will run out by gravity. If the pipe is sagged at any point, the water retained will have to be blown out with the lungs. If the pipe is trapped by reason of its course, the trap is, or should be, provided with a drain cock, and this must also be opened to insure thorough draining. Air-chambers usually drain without attention as they are only partially filled by compression of the air trapped in them, and when the pressure is off, the air expands again and drives the water out.

While speaking of draining pipes, it may be well to mention the draining and protection of waste traps from frost as well. Closet tanks can be drained by simply pulling the chain when the water is off. The bowl may be emptied with a sponge or rag; but, as communication would thus be opened between the house and soil pipe, this plan is not advised for any kind of trap. Common salt added to the water in the trap will prevent freezing until the contents chill below zero, Fahrenheit. Caustic soda lowers the freezing point, and may be used in earthenware with impunity; but while it has shown no noticeable effect on metals, it should be used with caution, if at all, in both metal and porcelain-enameled iron fixtures. Glycerine and wood alcohol added in equal parts to make a 30 per cent solution in the trap or fixture, will prevent freezing above zero. If the house is being drained for a considerable period of disuse, the best anti-freezing and seal-protecting filling for ordinary traps is, perhaps, glycerine alone. It has the advantage of doing no injury whatever to any material used in such goods, and it will not evaporate.

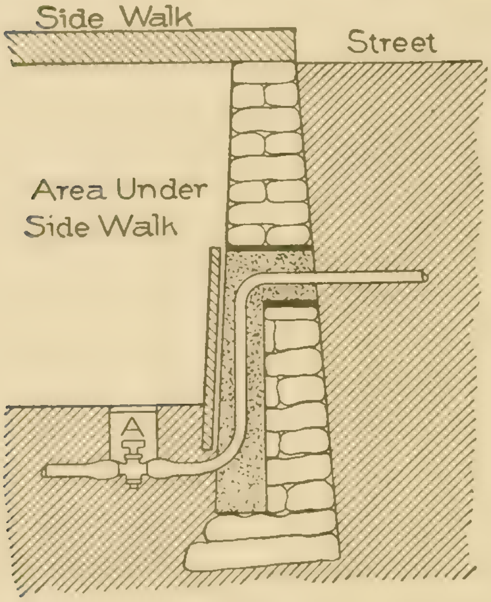


Fig. 70. One Method of Protecting Service Pipes from Frost. Pipe Carried through Wide Channel in Wall and Packed in Mineral Wool.

While it is sometimes necessary to place pipe in exposed positions, plumbing is not satisfactory if so exposed as to freeze during regular occupancy of the house; and every precaution should be taken to locate the fixtures and design the pipe system so that freezing will be unlikely. When exposure cannot be avoided, placing the hot service below the cold on horizontal runs; providing circulation in the hot service so placed; provision for circulation in, or otherwise warming, the cold service; and employment of liberal air-chambers, may singly or otherwise reduce the trouble from freezing to a minimum. Fig. 70 illustrates the precaution taken in one instance to protect the service in a cold-climate job. Water for the whole job always depends upon the service being in working order, and in this case the character of the ground prohibited drilling down to carry it under the area wall. The wall is shown liberally channeled, thus making three walls and the ends of the box of stone. The pipe is packed in mineral wool. The main stop and waste cock is shown at *A*.

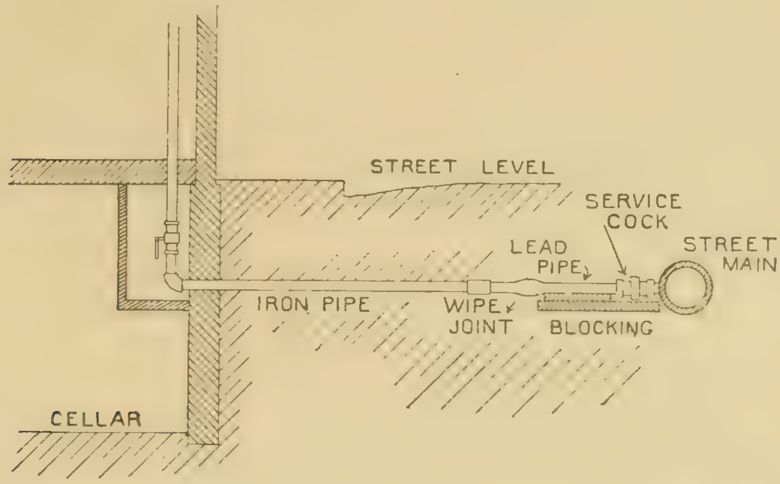


Fig. 71. Iron Service Pipe Connected to Street Main by Lead Pipe to Secure Flexibility and Avoid Effects of Settling

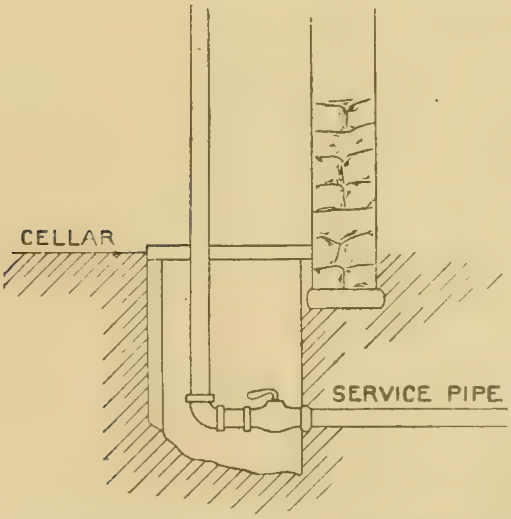


Fig. 72. Service Pipe Carried beneath Foundation Wall.

Fig. 71 shows a method of securing flexibility necessary to compensate for settling when connecting an iron service pipe with the street main, a section of lead supply being wiped in next the main. The service box and stop-cock at the curb are not shown in the engraving. The earth under the pipe should be rammed down solid after the connections are made, so that pressure from above will not break the connection or strain the cock. The connections between the lead and iron pipes should be made by means of brass ferrules and wiped joints. A stop and waste cock should be placed in the service pipe just inside the cellar wall, and in a position where it will be accessible in case of accident. A drip pipe should be connected with the cock tube, for draining away the waste water, which would otherwise saturate the frost-proofing and chill the pipe by conduction.

Simple boxes with multiple walls with air-space between, may be employed in protecting pipes against frost; or a single box with mineral wool, hair, felt, shavings, or granulated cork may suffice. When the service is brought under the foundation before entering the cellar, as shown in Fig. 72, frost-proofing is seldom necessary.

DIRECT SUPPLY

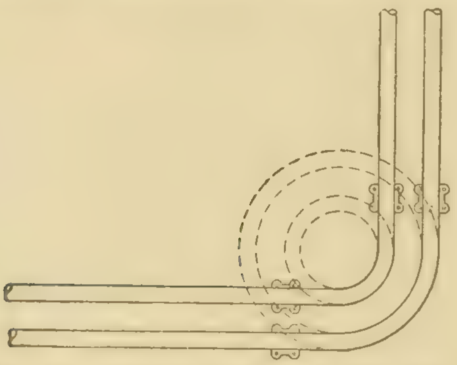
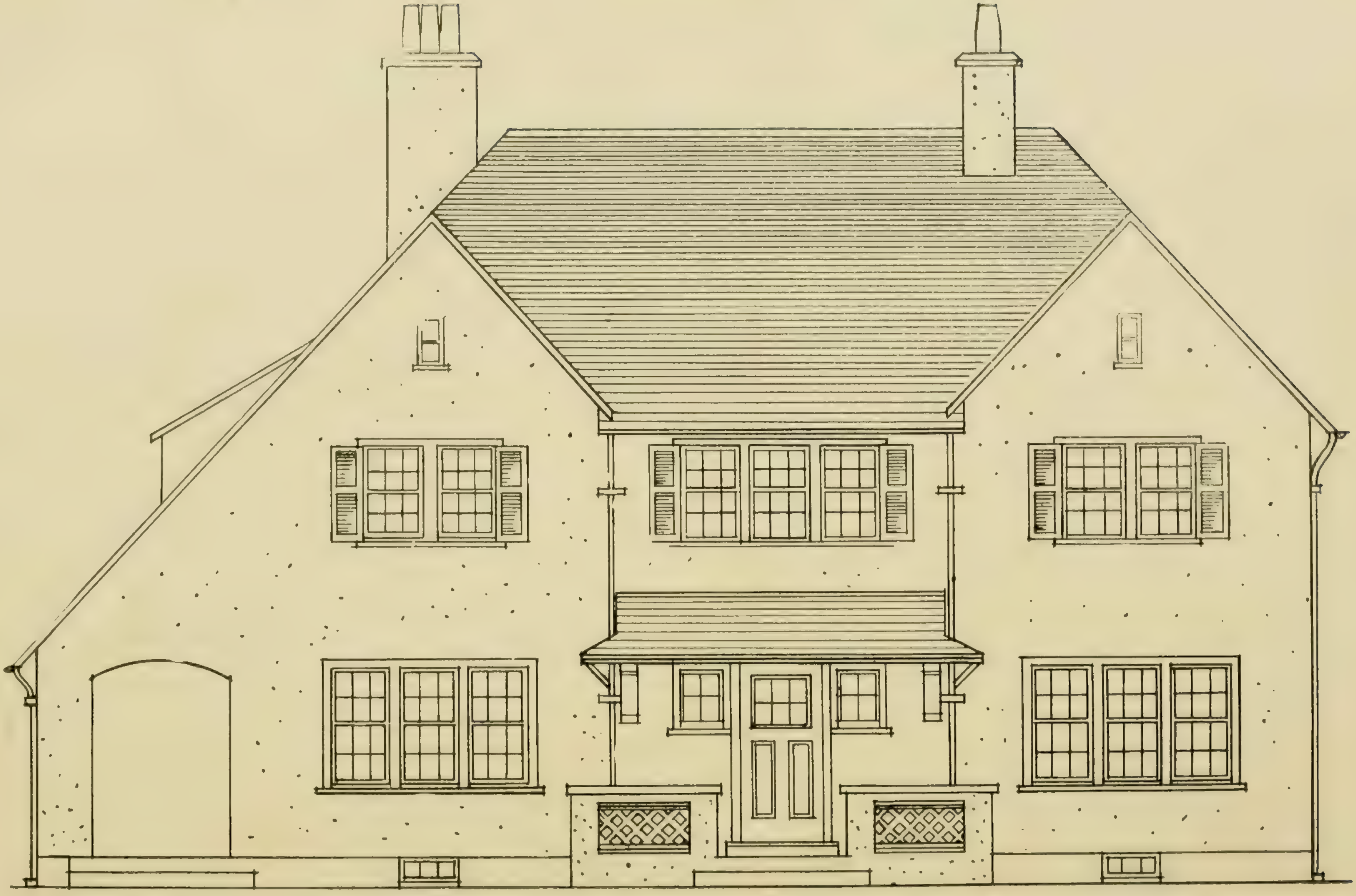


Fig. 73. Method of Laying Out Concentric Bends in Parallel Pipes.

The salient features of the supply system for city pressure, not already mentioned, are; separate shut-off cocks for the supplies of each fixture; separate lines to each isolated fixture or to each group of fixtures; $\frac{3}{4}$-inch supply to all sinks, trays, and baths; $\frac{1}{2}$-inch supply to water-closet tanks; and $\frac{1}{2}$ or $\frac{3}{8}$-inch branches for lavatories; no traps in supply lines; return circulation from lavatory hot supply so that hot water can be drawn instantly at the lavatory faucet; storage cylinder for hot water amply large to furnish a hot bath without robbing the hot service for other purposes; faucet on sediment pipe, so that water can be drawn at that point when desired; and proper stove connection. All shut-offs in direct-pressure work, except where located immediately at the fixture, should be *stop and waste,* with the waste on the house or fixture side.

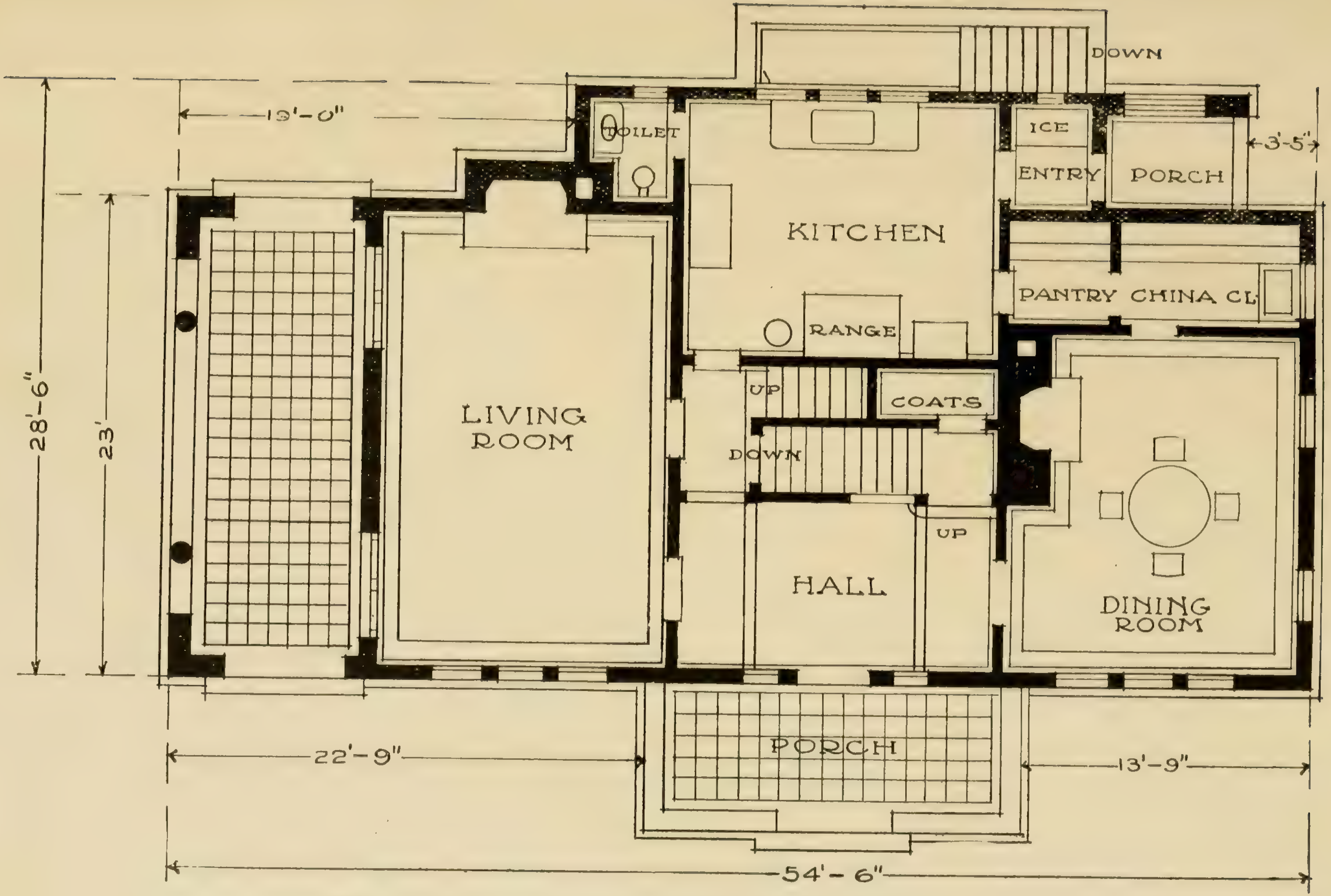
On single runs of lead pipe, make all bends on the same size of pipe, of the same radius. Make no bend on any size pipe, except tubing, of less than 3-inch radius to the center of the pipe. Give $\frac{5}{8}$ and $\frac{3}{4}$-inch pipe bends 3-inch radius; and $\frac{7}{8}$ and 1-inch pipe bends, 4-inch radius. Where two pipes of different size run together and bend in opposite directions, give the bend of the smallest pipe the radius prescribed for the bend in the larger one, if practicable.



FIRST PRIZE DESIGN, GARDEN CITY COMPETITION, LONG ISLAND, N. Y.

J. Lovell Little, Jr., Architect, Boston, Mass.

First-Floor Plan Shown on Opposite Page. For Second-Floor Plan, See Page 315.



FIRST-FLOOR PLAN, GARDEN CITY COMPETITION, LONG ISLAND, N. Y.

J. Lovell Little, Jr., Architect, Boston, Mass.

Front Elevation Shown on Opposite Page. For Second-Floor Plan, See Page 315.

TABLE III

Data Relating to Offsets

Bend	Equal to	Multiply by
$\frac{1}{6}$	60°	1.15
$\frac{1}{8}$	45°	1.414
$\frac{1}{12}$	30°	2.00
$\frac{1}{16}$	$22\frac{1}{2}$°	2.61
$\frac{1}{32}$	$11\frac{1}{4}$°	5.12
$\frac{1}{64}$	$5\frac{5}{8}$°	10.22

Where more than one pipe bend in the same direction, make the bends of the pipes form arcs of concentric circles as shown in Figs. 73 and 74. To set off the offsets in Fig. 74, draw line *A*, at the end of the first bends; and with the proper radii, describe the arcs that outline them. Set off one-eighth of the circumference of the circle corresponding to the larger arc, and draw line *C*, cutting the center of the circle. Then produce dotted line *D*, and set off a square the diagonal of which will give the straight pieces of the offset desired; and produce *E* parallel to *C*. Next describe the arcs outlining the second bends, finding the center on *E* from radius equal to the corresponding radius at *A*, which will be at the intersection of *E* and *B*. This brings the offset parts the same distance apart as the runs are. To accomplish this result with iron pipe, the centers of 45-degree fittings would have to be placed at the intersections of tangents of the arcs, thus throwing the fittings in a line deviating $22\frac{1}{2}$ degrees from one perpendicular to the run. This plan is the strictly correct way; but on account of the difficulty of laying out the work, it is more usual

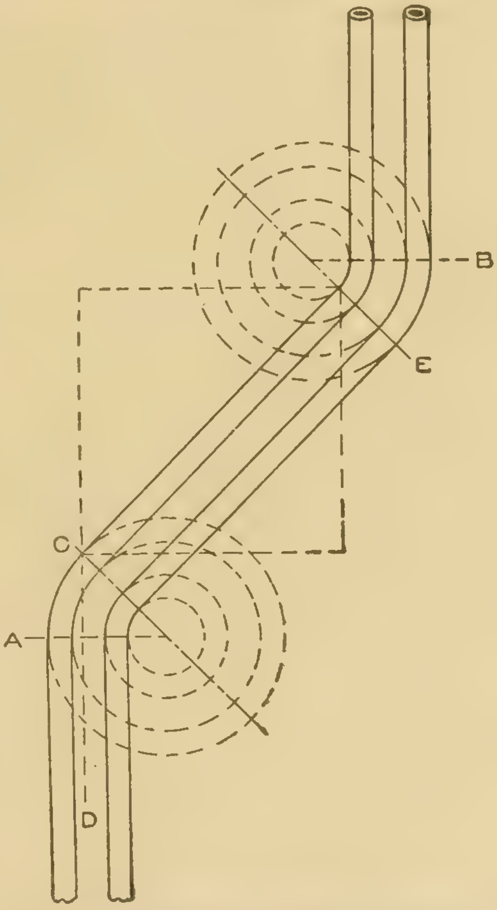


Fig. 74. Method of Laying Out Offset in Parallel Pipes to Preserve Equal Distance between Them.

to line up offset fittings perpendicular to the runs, and let the offset pieces fall, as they will, nearer to each other, center to center, than are the lines of the runs.

Offset pieces from center to center of fittings exceed in length the distance offset in the ratio indicated by the constants given in the accompanying table. To find the length of an offset piece, center to center of fittings, simply multiply the distance the line is to be offset, by the constant given for the particular fittings to be used.

Water Supply to Fixtures. In a small installation, the running of a separate supply to each fixture is desirable. There is, however, a limit to the number of fixtures and isolated location of them, beyond which the furnishing of separate supplies to each faucet is folly, as, in addition to the confusion of pipes, and the expense, it leaves more material open to possible failure, and does not reduce the chances of lack of service in proportion, the sole object of separate supplies (and of cocks, too) being to avoid losing the service of other fixtures during times when one of them, or its supply or waste, must be repaired.

In a residence job, two main supplies to each bathroom, with separate stops for each fixture, are sufficient; and a return circulating pipe from the lavatory will serve every purpose, as the water is kept hot in the main line to the bath branches.

The pump and kitchen-sink work of a country job of this type is shown in Fig. 75. The pump air-chamber discharge leads up to and over tank. An opening near the pump provides for elevating water by other means if desired. The pump faucet is piped up and over so as to discharge into sink. The tell-tale pipe from tank leads down behind sink-back and out through a nozzle, as shown. The sink supplies are fitted with stop-cocks. The pressure being light, there are no air-chambers to the sink faucets. The supply to pump is from a large cistern.

Fig. 76 shows the supplies of the same job, on the kitchen ceiling. The system provides positive circulation to keep hot water near the bathroom fixtures. The hot supply is on the left side for each fixture. There is only one pipe crossed, and it does not interfere with draining the job. There are no traps in the supplies, nor drain cocks, to be forgotten. There is a relief line from the reservoir to the tank, so that it is not possible to close every means of escape for vapor or steam

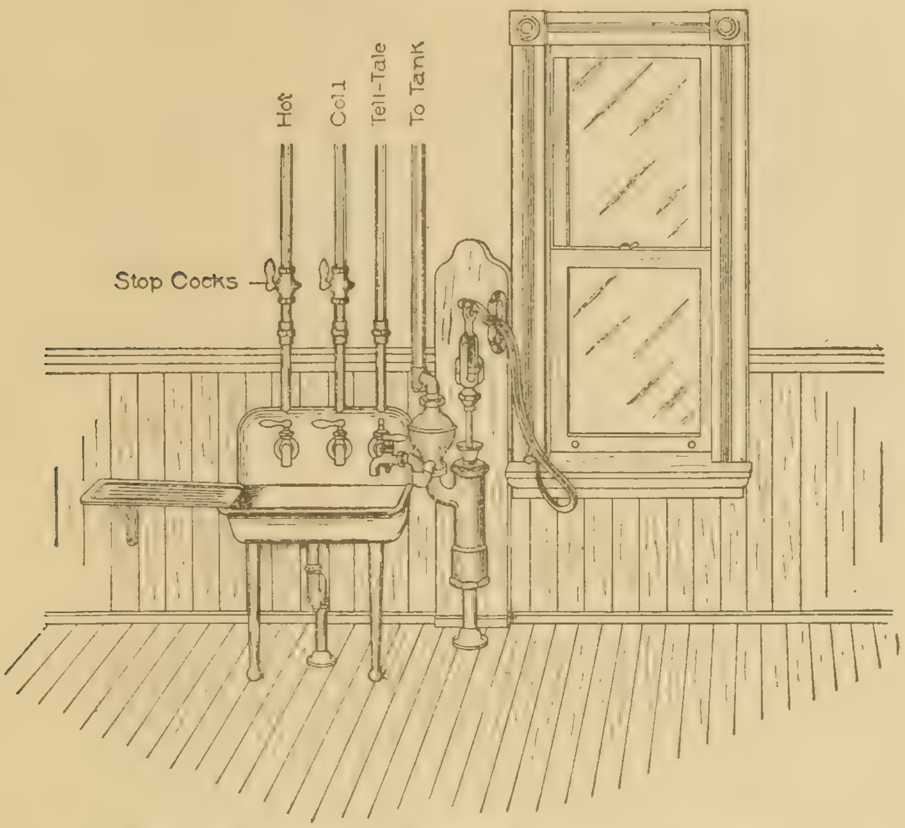


Fig. 75. Pump and Kitchen-Sink of a Country Installation.

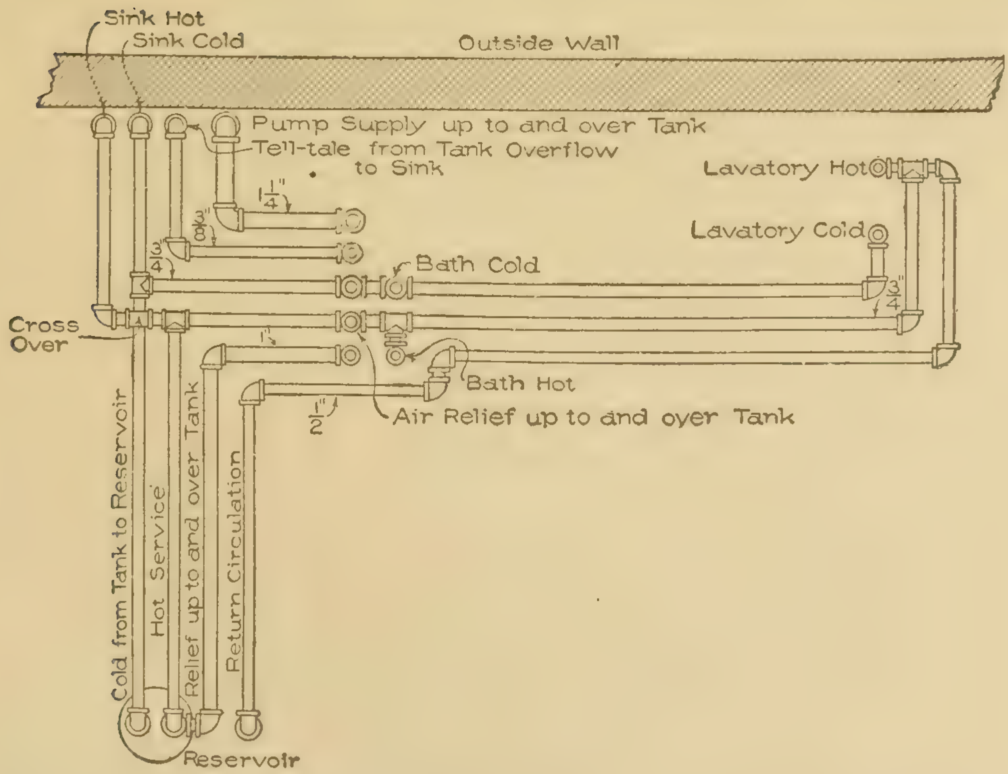

Sink Hot
Sink Cold
Outside Wall
Pump Supply up to and over Tank
Tell-tale from Tank Overflow to Sink
Lavatory Hot
Lavatory Cold
1 1/4"
3/8"
3/4"
Bath Cold
3/4"
Cross Over
1"
Bath Hot
1/2"
Air Relief up to and over Tank
Cold from Tank to Reservoir
Hot Service
Relief up to and over Tank
Return Circulation
Reservoir

Fig. 76. Plan Showing Layout, on Kitchen Ceiling, of Supply Pipes in Installation Shown in Fig. 75.

from the reservoir. The hot supply and cold service are both open to the air at the tank.

The disadvantage of this job is that the cocks which stop the hot water to the bathroom are over the reservoir. While each fixture is controlled separately, by cocks in addition to its regular faucets, all the lines are not under control individually. This arrangement embraces every feature essential to good service and with the least possible material. The nickeled supply in bathroom is thus reduced to a minimum, and the chances for leakage to do damage are greatly lessened. For comparison, the kitchen work of an actual installation with separate supplies, having one bathroom and three odd fixtures, is shown in Fig. 77. This number of fixtures is considered about the limit in strictly separate supply work for residences, when all the lines radiate from one point, as they do in this case. In order that their purpose may be understood, the pipes shown in Fig. 77 are numbered. Pipe 1 carries the water from the house force-pump to the tank, and is arranged to discharge over the top of the tank. The tell-tale pipe, 2, is from the tank, and discharges in the sink, so that the person using the pump will know, when water flows from it, that the tank is full to overflowing. The cold-water supply to the butler's sink is No. 3. No. 4 is the hot-water supply to the same fixture. Pipe 5 is the return circulation from the bathroom hot supply. To make proper circulation certain at all times, regardless of the trap in the hot-service pipe made by dropping from the boiler and running across under the sink before rising to the second floor, the hot-service pipe is continued to the attic and a return made from there, an air-pipe being taken from the highest point over the tank, to prevent its becoming air-bound. The position of the stop-cocks is such that they will drain without giving special attention to the waste water, which discharges into the sink; and the cocks are within easy reach from the floor. Pipe 6 is the cold-water supply to the bathroom fixtures. The supply to the water-closet tank is taken from pipe 9, which passes under the closet room, a cock being placed just above the floor. Pipe 7 is the hot-water supply to the bathroom fixtures. The main cold supply from the tank is pipe 8, which has a cock over the sink, and is also provided with a valve at the tank. Pipe 9 supplies cold water to the laundry, the hall lavatory, and the water-closet already mentioned. Pipe 10 supplies hot water to the laundry and the hall lavatory.

All of the service pipes, both hot and cold, above the first floor, are continued upward from the kitchen ceiling through a partition to and over the tank. This allows air to enter the pipes and drain the lines when the stop-cocks on them are turned off.

Baths do not need circulation for the same reason that lavatories do. Lavatory faucets are small in nozzle, as a rule; only small quantities of water are needed at a time; and it is annoying to have to waste time in drawing out cold, "dead" water and enough more to warm the pipe line, before warm water can be had at the faucet. Where the water must be pumped by hand this is still more aggravating. Kitchen sinks are close to the hot supply source, and do not need circulation. Lavatories and other fixtures remote from the bath or main toilet room, are sometimes served from the circulating loop instead of separately.

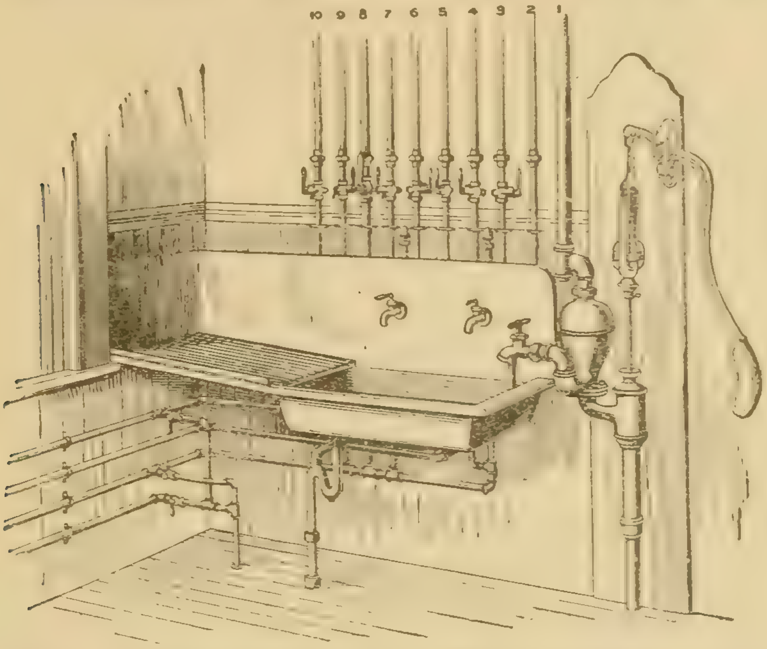


Fig. 77. Kitchen Arrangement of a Separate Supply Tank Installation.

Hot-Water Storage. The storage cylinder for hot water is made in both horizontal and vertical types. When heated by stove connections, the vertical type, shown in Fig. 78, is best; and this type is usually employed. The only difference in the standard makes is the position of the connections. Both vertical and horizontal types are connected and operate on the same principles, and the arrangement of one may be deduced from the *modus operandi* of the other. The vertical type, for example, of iron or mild steel, galvanized inside and out, single- or double-riveted, heavy, and calked according to pressure designed for, is generally divided into two classes—*Standard* and *Extra Heavy*. Seamless copper cylinders, reinforced inside for heavy work, are made.

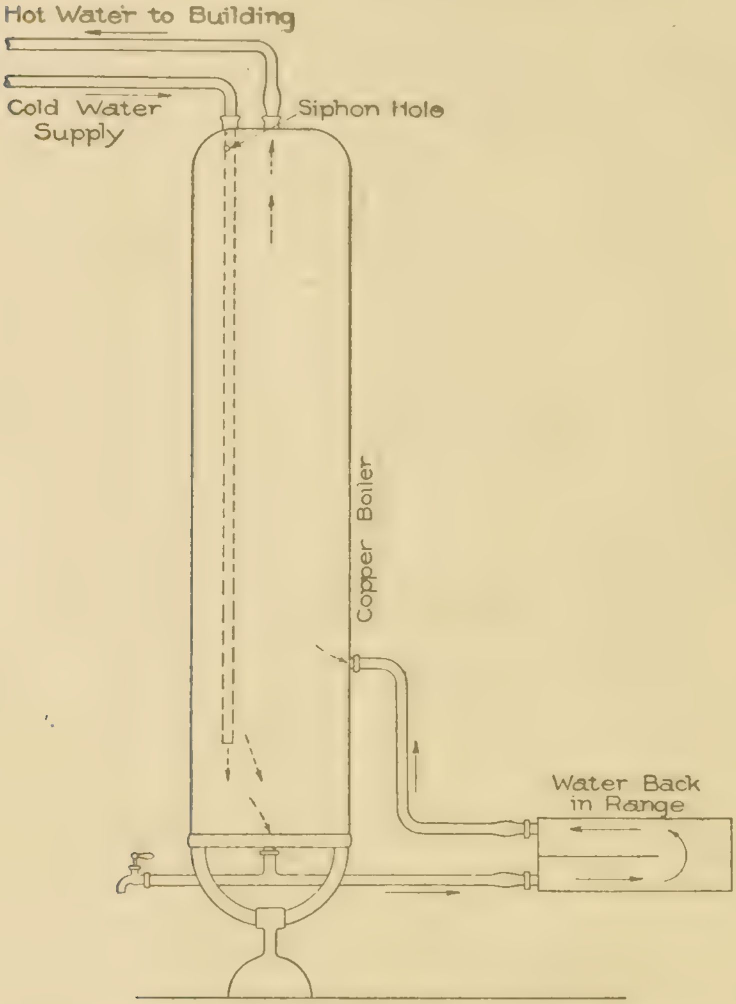


Fig. 78. Vertical Type of Hot-Water Storage Cylinder Adapted for Range Heating.

The light copper shells for light pressure, not reinforced, are collapsible under partial vacuum, and frequently do collapse when the supply is being drained, on account of the delivery failing to admit air to take the place of the water. Copper shells are also much more likely to rupture under strain than iron or steel shells. Take, for instance, a house with copper storage cylinder, with hot fire and in extremely hot water, as on wash-day; then, if the pressure is suddenly reduced by opening a faucet or otherwise, and the temperature is far above the boiling point of the water under the remaining pressure, the tendency is for the whole volume of water to turn instantly to steam. This has happened with disastrous effect in more than one instance, the copper shell being ripped and spread out almost in a plane.

Rumbling noise is frequently heard in any type of reservoir. Water being heated throughout, or perhaps only at some points in the stove, to above the boiling point corresponding to the pressure, steam bubbles form in the hottest places and crowd the water-back into the main or into the air-chambers to make room for themselves. It is the concussion caused by the collapse of these bubbles forming and condensing in rapid succession, that creates the rumbling noise. This condition sometimes results from a brisk fire when the reservoir water is not overheated, and is due to air-traps in the connection, or constriction by incrustation or otherwise. Rumbling under this condition is a cause for prompt investigation.

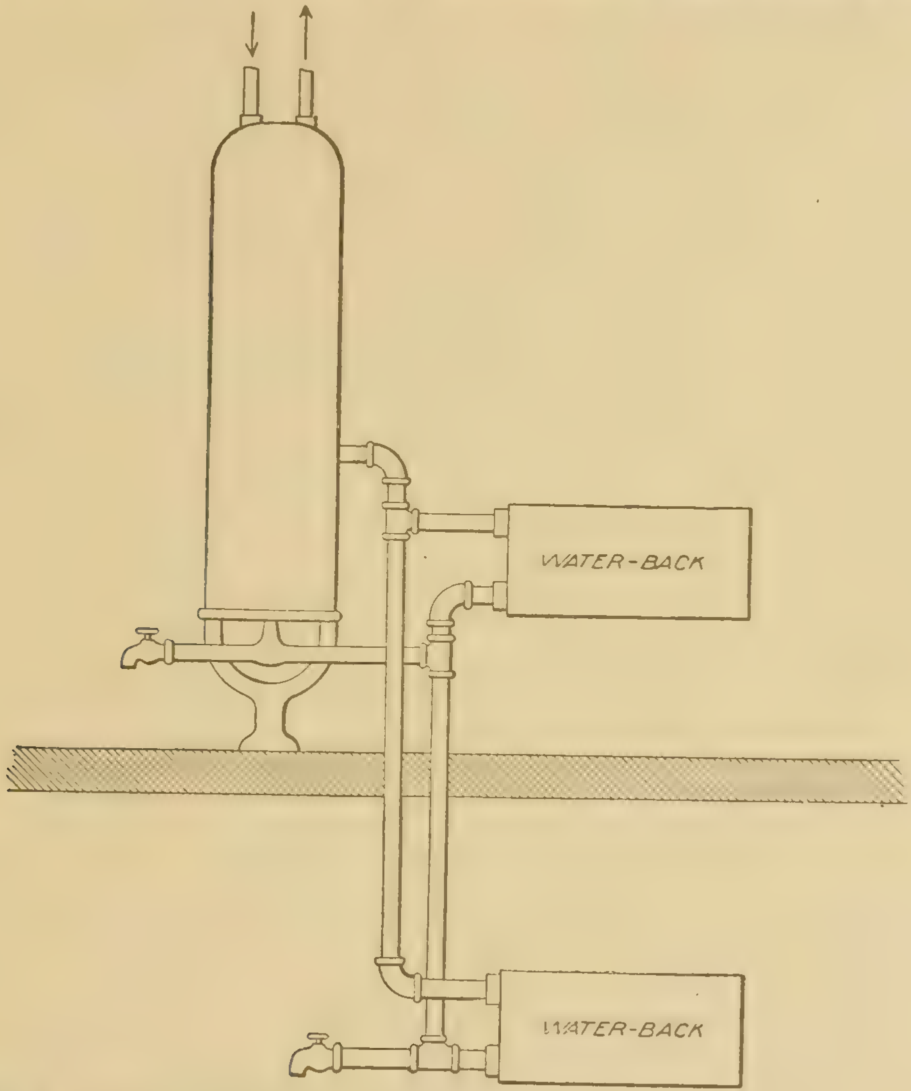


Fig. 79. Method of Connecting Reservoir to Two Water-Backs on Different Floors.

The means of heating may be a cast back or front, or a hand-made pipe coil in the firebox. Air-traps favoring the formation of steam are occasioned by wrong inclination of the connection, by reduction of its diameter in the horizontal part, or by the upper hole of a cast back being tapped below the top of the water cavity. The bottom of a reservoir is below the firebox level when placed on the regular stand. When it is desirable to connect a reservoir with two water-backs, one in the kitchen range for regular service and another in a laundry stove in the cellar, the plan of connecting them seen in Fig. 79 is proper. In this case, either stove may be used separately, or both together, as occasion demands. The sediment cock of the upper reservoir may be handy to draw from at times; but the lower one will be found to collect most of the sediment, and should be opened quite frequently to cleanse the water-back and connections.

In laundries, public bathrooms, etc., where a large amount of hot water is used, it is necessary to have a larger storage tank and a heater with more heating surface than can be obtained in the ordinary range water-back. Fig. 80 shows an arrangement for this purpose, using the horizontal type of storage tank. The tank may be of galvanized wrought iron or steel, any size desired, and is usually suspended from the ceiling by means of heavy iron stirrups. The heaters used are similar to those employed for hot-water house warming. The simplest method of making the connections is indicated in the illustration. If the supply is from a street service, or there are faucets on the storage tank supply below the hot storage reservoir level, making it possible for the tank to become empty through those faucets or failure of the street supply, there should be a check-valve in the cold-water connection.

The *capacity of the heater and tank* employed will depend upon the amount of water used. In some cases a large storage reservoir and a comparatively small heater are preferable, and in others the reverse is more desirable.

The required grate surface of the heater may be computed as follows:—First determine or assume the number of gallons to be heated per hour, and the required rise in temperature. Reduce gallons to pounds by multiplying by 8.3, and multiply the result by the rise in temperature to obtain the number of thermal units. Assuming a combustion of five pounds of coal per square foot of grate, and an efficiency of 8,000 thermal units per pound of coal, we have the formula:

$$\text{Grate surface in sq. ft.} = \frac{\text{Gal. per hour} \times 8.3 \times \text{Rise in temp.}}{5 \times 8{,}000}.$$

Example. How many square feet of grate surface will be required to raise the temperature of 200 gallons of water per hour from 40 degrees to 180 degrees? Substituting values in the above formula, we have:

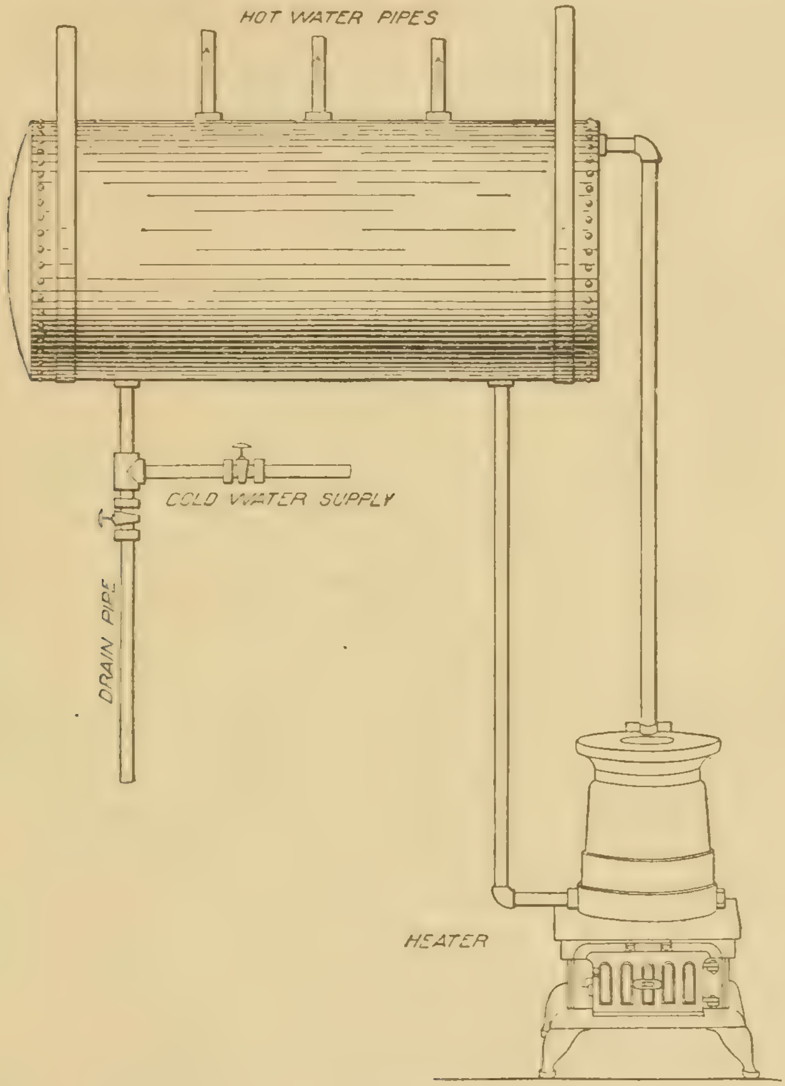


Fig. 80. Horizontal Type of Hot-Water Storage Cylinder Connected to Heater.

$$\frac{200 \times 8.3 \times (180 - 40)}{5 \times 8{,}000} = 5.8 \text{ square feet.}$$

In computing the amount of water required for bathtubs, it is customary to allow from 20 to 30 gallons per tub, and to consider that the tub may be used three or four times per hour as a maximum during the morning. This will vary a good deal, depending upon the character of the building. The above figures are based on apartment hotel practice.

Storage cylinders or reservoirs for hot water are often called *boilers,* but will henceforth be referred to as *reservoirs.* A stove or range connection is essentially described as follows: The sediment pipe should terminate in a faucet at the lowest point in the bottom connection, which connection should rise continuously from the lowest point to the bottom hole in the heater. No direct connection should ever be made between the water supply pipes and the drain. Even if such a connection is above the trap of a fixture, there is some danger that foul liquids or gases may penetrate for some distance into the supply pipes and thus afford a possibility of contamination of the water supply. The upper connection should rise continuously from the upper hole of the heater to the hole in the side of the reservoir; or, if preferred, in order to get hot water instantly after the fire begins, the upper connection may rise and connect into the main hot service over the reservoir. The circulation will be the same; but in general, connecting at the hole in the side gives best results, though in this case the first portion of water heated mingles with the balance in the upper end of the reservoir, and the following portions in succession, so that no *hot* water can be obtained until all the water above the side hole is warmed. The bottom hole serves for emptying, cleansing, and circulation to the stove.

The return circulation is always connected to the bottom pipe of the stove connection, as shown in Fig. 81, in which the hot service and circulating pipe are represented by dotted lines. The side hole is simply to receive the water from the stove. There are, or should be, two holes in the top, one in the center of the head, and the other about half the radius in the direction of the side hole. The eccentric hole is for cold-water entry. The cold supply might be admitted at the bottom, but the result would be to empty the reservoir when the house supply is turned off. The cold supply is not emptied abruptly into the top of the reservoir. A delivery pipe is extended to very near the bottom, say within two or three inches, so that the water will mingle directly with the coldest portion near the bottom, where it begins its journey to the stove to be heated. The usual way is by simple open-end pipe, but the end of the pipe should be plugged and holes drilled in the pipe and plug so as to form a spray delivery. This does not aid the delivery or heating at all, but the spray will scour the bottom and sides adjacent when the reservoir is emptied and flushed to rinse out scale and sediment. Immediately under the upper head, the delivery pipe must have a $\frac{1}{8}$-inch hole drilled in, so that air will enter and break the siphon, and thus avoid inadvertently emptying the reservoir when intending only to cut off the supply and drain the pipe. See Fig. 78.

The *siphon hole,* as it is termed, should be turned in the direction opposite the eccentric hole, which is for the hot-water exit, so that the stream of cold water which issues there when water is coming into the reservoir will not cut across and interfere with the hot service which is always leaving the reservoir at the same time. If the delivery were placed nearest the side hole, hot water from the stove would have to pass around it in order to reach the exit. Delivering the cold through a pipe passing down through the volume of hot water is no material retardation of the heating process. The heat thus absorbed by the cold delivery is simply that much aid to the ultimate purpose. This cannot be said of the siphon-hole jet when directed across the hot exit or in its direction.

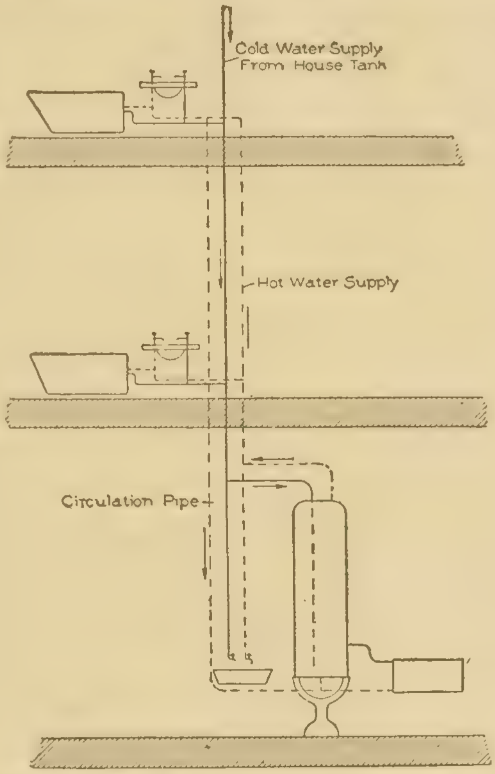


Fig. 81. Pipe Connections to Heater and Fixtures. Hot Service and Circulating Pipe Shown by Dotted Lines. Return Circulation Connected to Bottom Pipe in Water-Back.

The object in putting the siphon-hole near the upper head is to avoid siphoning more water than necessary, as the waste tubes of stop and waste cocks are generally left open—not connected to drains, and often not even discharging where the waste can be left to take care of itself. Moreover, it is a waste of the stored hot water to siphon out several inches from the hottest point.

Care should be taken not to have the hot connection extend into the upper head below the inner surface, as this would form an air-space which could not be filled with water, and thus annoying noise and the formation of steam would be favored, if no other consequence presented itself.

It is essential to keep the water-back or coil filled. Sometimes the supply may be off for a day or so. No water can then be drawn at the regular faucets; and extreme care should be taken not to draw too much from the sediment faucet, as this is the time when temptation to use it is hard to overcome. The reservoir full will keep the level above the side hole for weeks, if none is deliberately drawn out. The height of the water can be told by tapping on the shell, and in no case should it be allowed to fall below the side opening; neither will it do to empty the reservoir and use the fire with the back empty. Either keep water in the reservoir in cases of emergency, or remove the water heater altogether and substitute a tile back until regular water supply can be had. A reservoir can be replenished with a pail and funnel, by hand, by loosening one of the top connections.

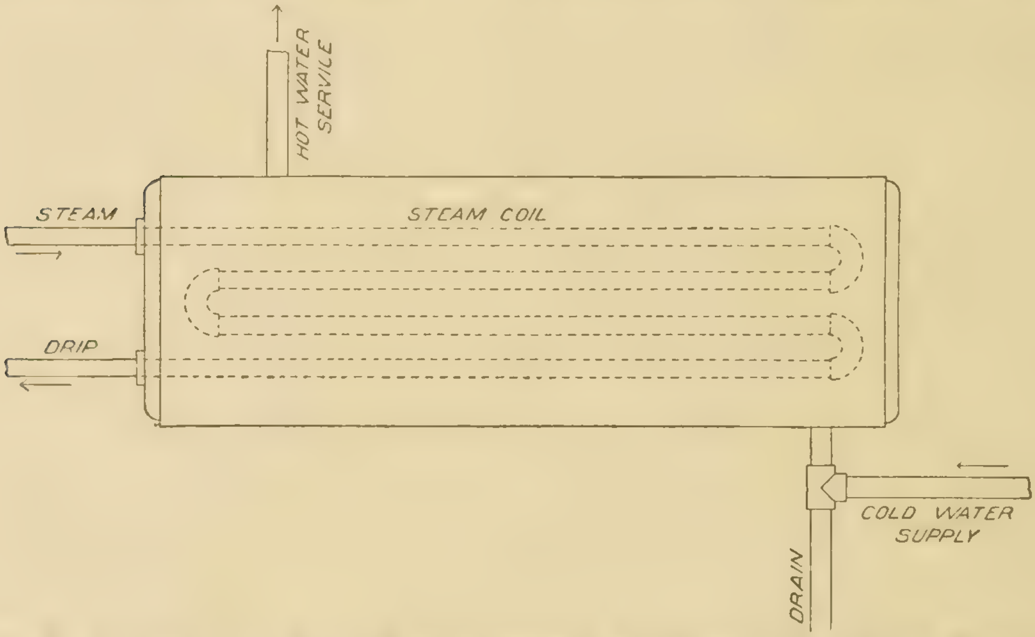


Fig. 82. Horizontal Hot-Water Storage Reservoir with Steam Coil of Brass Pipe for Heating. Used Where Steam Pressure is Constantly Maintained.

In apartment or other houses where steam pressure is constantly maintained, the whole plumbing system is usually supplied with hot water through the medium of a reservoir provided with steam coil of brass pipe, as shown in Figs. 82 and 83. The *trombone coil*, illustrated in Fig. 82, can be used only on horizontal tanks; it would not drain in any other position. The water of condensation is generally wasted into the sewer, delivered to a hot well, or returned by steam trap. Steam heat in such instances takes the place of the water heater used in stoves and ranges in general domestic work.

The efficiency of a steam coil when surrounded by water is much greater than when placed in the air. A brass or copper pipe will give off about 200 thermal units per square foot of surface per hour for each degree difference in temperature between the steam and the surrounding water. This is assuming that the water is circulating through the heater so that it moves over the coil at a moderate velocity. The ratio of absorption decreases as the temperature of the water approaches that of the steam surface. In assuming the temperature of the water, take the average between that at the inlet and that at the outlet.

Example. How many square feet of heating surface will be required in a brass coil to heat 100 gallons of water per hour from 38 degrees to 190 degrees, with steam at 5 pounds' pressure?

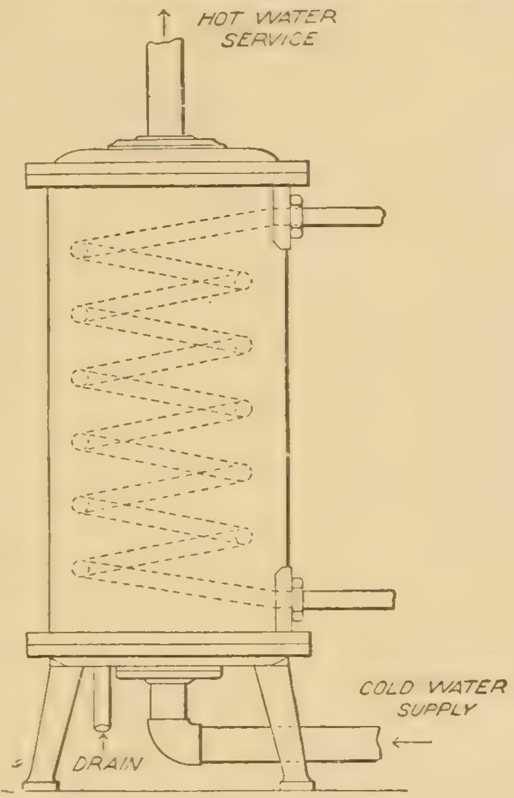


Fig. 83. Vertical Storage Reservoir with Steam Coil of Brass Pipe for Heating. Used Where Steam Pressure is Constantly Maintained.

Water to be heated $= 100 \times 8.3 = 830$ pounds.

Rise in temperature $= 190 - 38 = 152$ degrees.

Average temperature of water in contact with the coils

$$= \frac{190 + 38}{2} = 114 \text{ degrees.}$$

Temperature of steam at 5 pounds' pressure = 228° approximately (actually 227.964°).

The required B. T. U. per hour $= 830 \times 152 = 126{,}160$.

Difference between the average temperature of the water and the temperature of the steam $= 228 - 114 = 114$ degrees.

B. T. U. given up to the water per square foot of surface per hour $= 114 \times 200 = 22{,}800$. Therefore, No. of feet of heating surface required

$$= \frac{126{,}160}{22{,}800} = 5.5 \text{ square feet.}$$

EXAMPLES FOR PRACTICE

1. How many linear feet of 1-inch brass pipe will be required to heat 150 gallons of water per hour from 40 to 200 degrees, with steam at 20 pounds' pressure? Ans. 21.3 feet.

2. How many square feet of grate surface will be required in a heater to heat 300 gallons of water per hour from 50 to 170 degrees? Ans. 7.4 sq. ft.

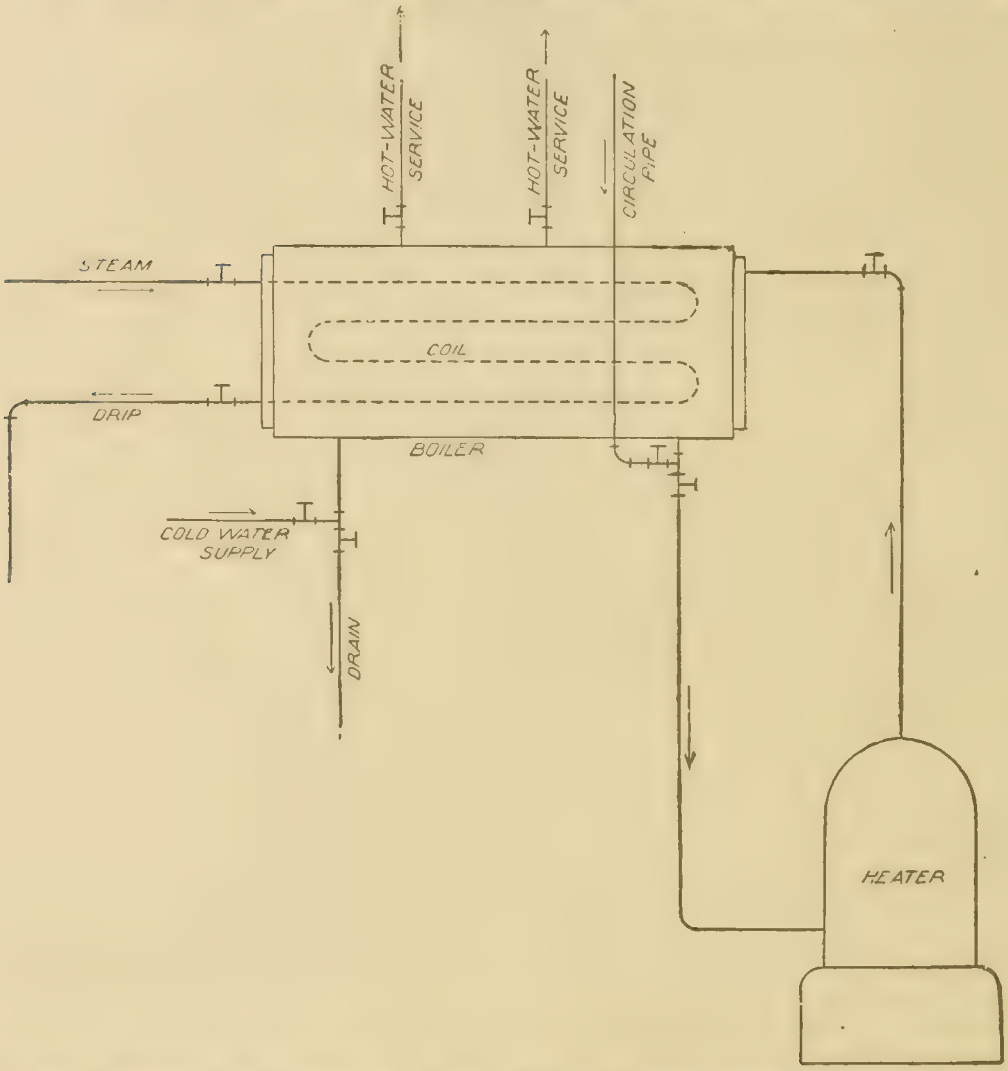


Fig. 84. Storage Tank Heated by Steam Coil in Winter; Cross-Connected to Coal Heater in Summer.

3. A hot-water storage tank has a steam coil consisting of 30 linear feet of 1-inch brass pipe. It is desired to connect a coal-burning heater for summer use, which shall have the same capacity. Steam at 5 pounds' pressure is used, and the water is raised from 40 to 180 degrees. How many square feet of grate surface are required? Ans. 5.9 sq. ft.

4. A hotel has 30 bathtubs, which are used three times apiece between the hours of seven and nine in the morning. The hot-water system has a storage tank of 400 gallons. Allowing 20 gallons per bath, and starting with the tank full of hot water, how many square feet of grate surface will be required to heat the additional quantity of water within the stated time, if the temperature is raised from 50 to 130 degrees?

Ans. 11.6 sq. ft.

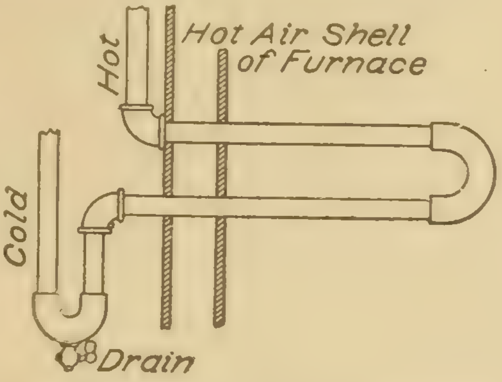


Fig. 85. Cross-Connection of Storage Tank to Firepot of Furnace.

If steam at 10 pounds' pressure is used instead of the heater, how many square feet of heating coil will be required? Ans. 15.3 sq. ft.

Sometimes a storage tank is connected with a steam-heating system for winter use, and cross-connected with a coal-burning heater for summer use when steam is not available. Such an arrangement is shown in Fig. 84. A cross-connection for the same purpose is often made to the fire-pot of the house-warming heater, as indicated in Fig. 85. A drain at the lowest point is essential, but so deep a dip as shown is not necessary.

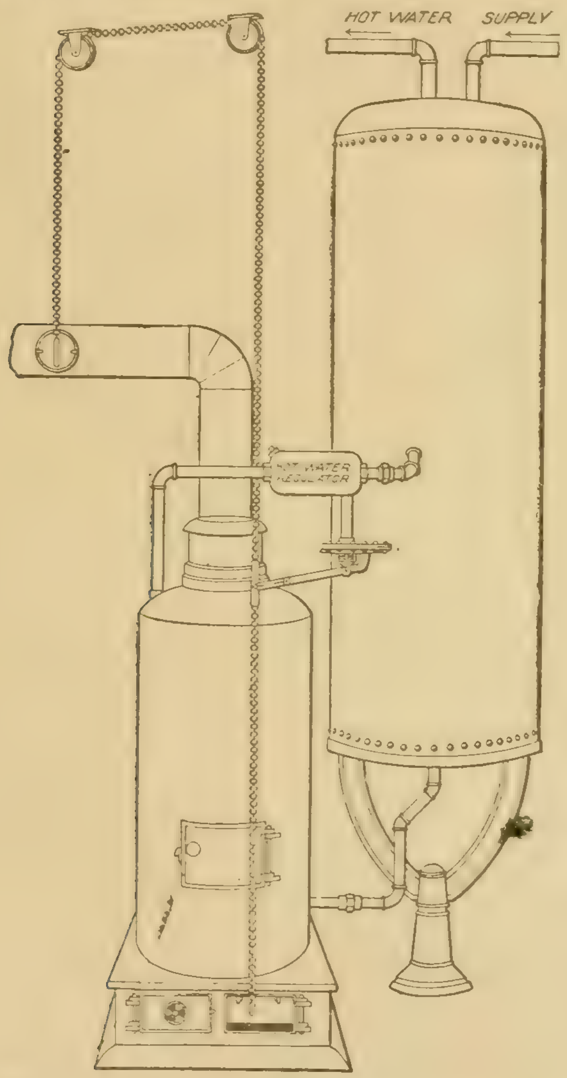


Fig. 86. Temperature Regulator Attached to Coal Heater.

Temperature Regulation. Hot-water storage tanks having special heaters or steam coils, should be provided with some means for regulating the temperature of the water. Fig. 86 shows a simple form attached to a coal-burning heater. It consists of a hollow casting about nine inches long, tapped at the ends to receive 2-inch pipe, and containing a second shell called the *steam generator*, shown in detail in Fig. 87. The outer shell is connected with the circulation pipe as shown in Fig. 86. The generator is filled with kerosene, or a mixture of kerosene and water, depending upon the temperature at which it is wished to have the regulator operate. The inner chamber connects with a space below a flexible rubber diaphragm in a sepa-

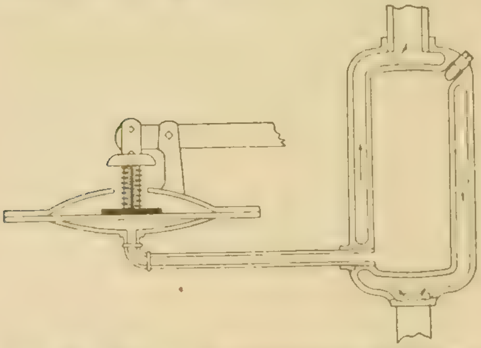


Fig. 87. Steam Generator of Temperature Regulator Shown in Fig. 86.

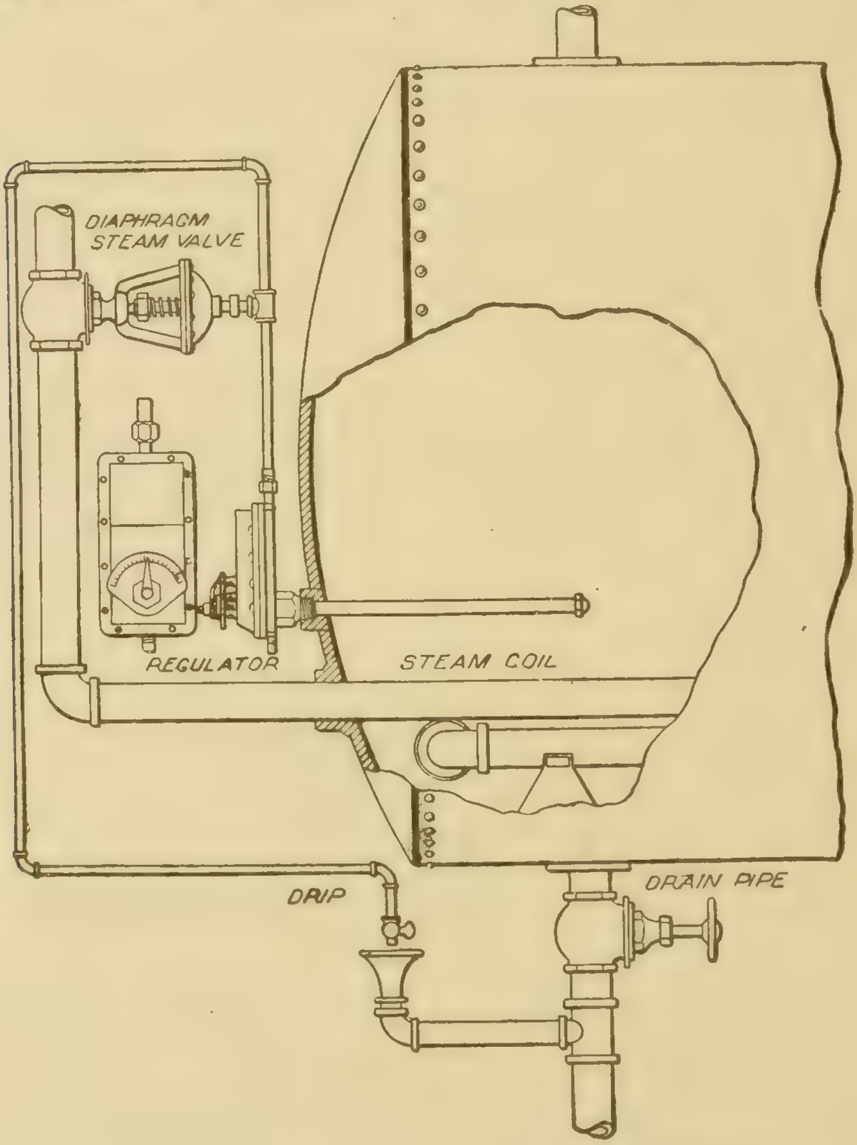
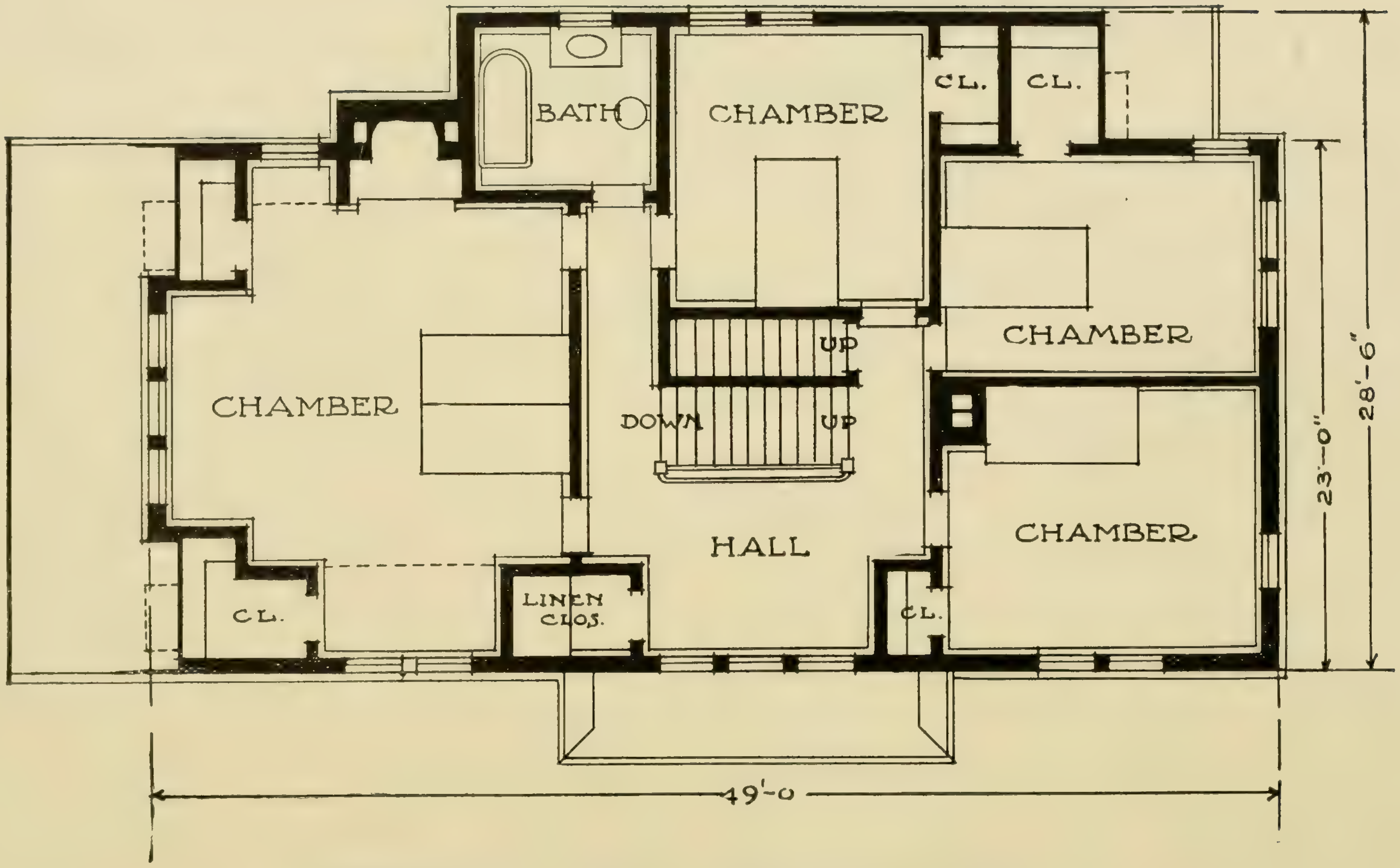


Fig. 88. Temperature Regulator Connected to Steam Coil.



SECOND-FLOOR PLAN, GARDEN CITY COMPETITION, LONG ISLAND, N. Y.

J. Lovell Little, Jr., Architect, Boston, Mass.

For Elevation and First-Story Plan, See Page 298.

rate case adapted to operate the draft lever. The boiling point of the mixture in the generator is lower than that of water alone, and depends upon the proportion of kerosene used, so that when the temperature of the water in the outer chamber reaches this point, the mixture boils, and its vapor creates a pressure which moves the diaphragm and closes the draft door of the heater, with which it is connected.

A form of regulator for use with a steam coil is shown in Fig. 88. This consists of a rod made up of two metals having different coefficients of expansion, and so arranged that the difference in expansion will produce sufficient movement to open a small valve when the water reaches a given temperature. This allows water pressure from the street main with which it is connected, to flow into a chamber above a rubber diaphragm, thus closing the steam supply to the coil. When the water cools, the rod contracts, and the pressure is released above the diaphragm, allowing the valve to open and thus again admit steam to the coil.

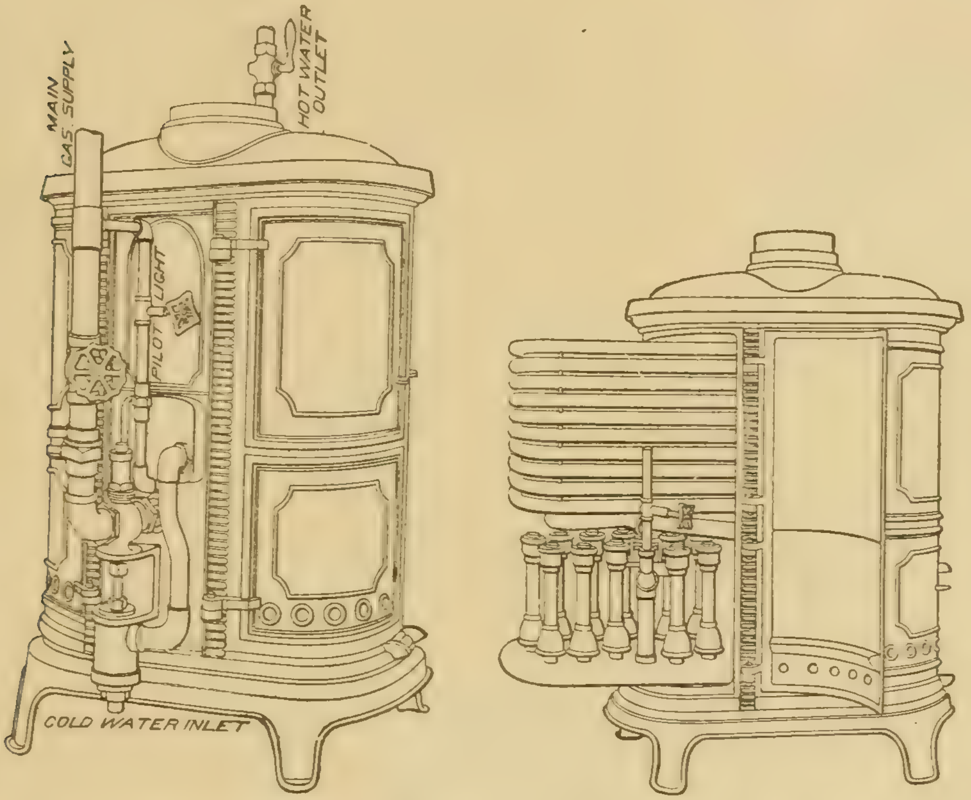


Fig. 89. Gas Heater with Automatic Mechanism for Controlling Hot Service. View at Right Shows Interior Coils.

Return circulation is provided in these installations in the way already described, being even more essential than in small jobs with shorter runs and fewer fixtures; yet one would think that the great number of fixtures served would insure at least one or another being in constant use, and thus keep warm water in the main lines without special provision for the purpose.

In cottages with no bath and with small culinary requirements, a 30-gallon reservoir is sufficient. Not less than 40 gallons should be employed for a bathroom job. The capacity of the average stove heater is even too great for 40 gallons' storage unless there is liberal use of hot water; but where gas is used and the water heating independent of the cooking heat, as it generally is, the temperature can be regulated to suit. A storage capacity of 52 gallons or more is usual for large residences.

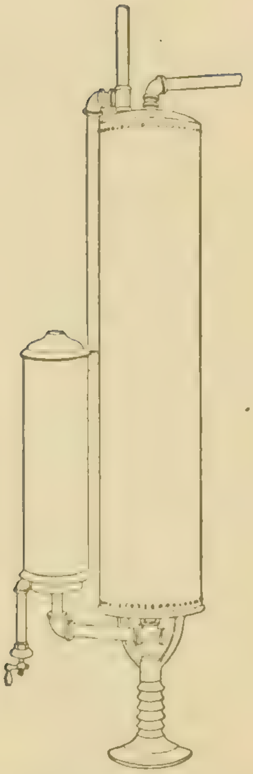


Fig. 90. Gas Heater Connected to Reservoir and Controlled by Thermostatic Valve Projecting into Latter.

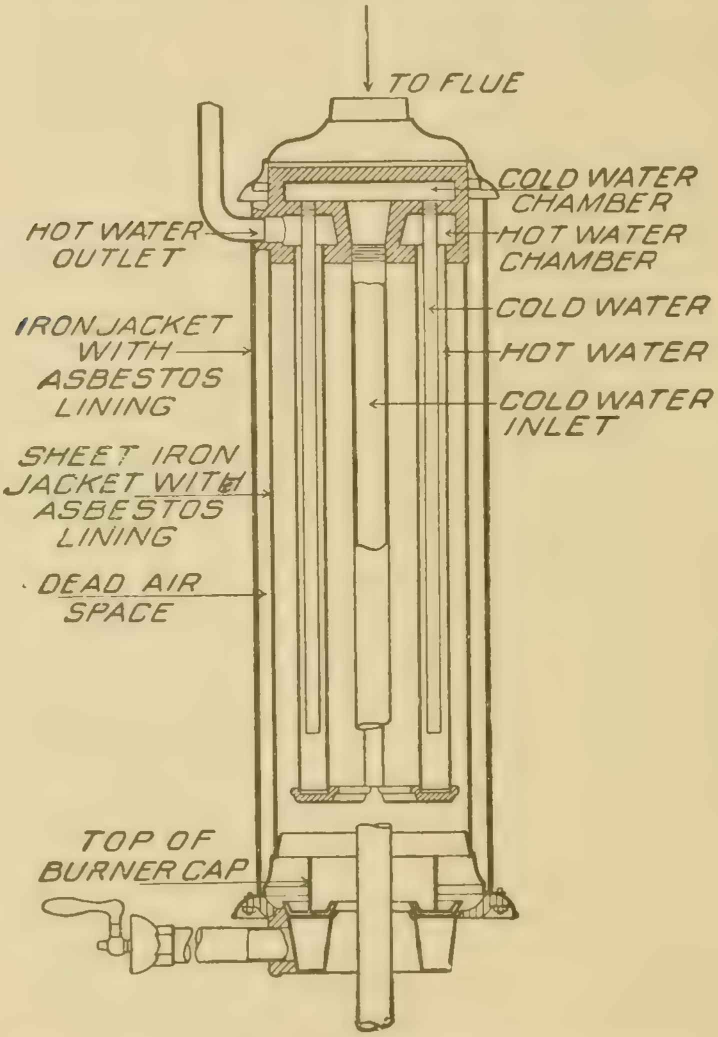


Fig. 91. Enlarged Section of Gas Heater Shown in Fig. 90.

Gas Heaters. There are gas heaters provided with thermostatic or pressure mechanism by which the hot service is taken care of automatically. The latter of these are simply connected in the line in a convenient place. In one type, the appearance and construction of which is shown in Fig. 89, simply opening any hot-water faucet reduces the pressure, and the gas is thereby turned on. A pilot light ignites it, and the supply is heated as fast as it passes through the copper coils of the heater. No storage capacity is required by this form. In another form, shown in Fig. 90, the heater is controlled by a thermostatic valve projecting into the regular reservoir used with it. When the water in the reservoir is heated to the desired temperature, the gas supply is reduced or cut off. A section of this heater is shown

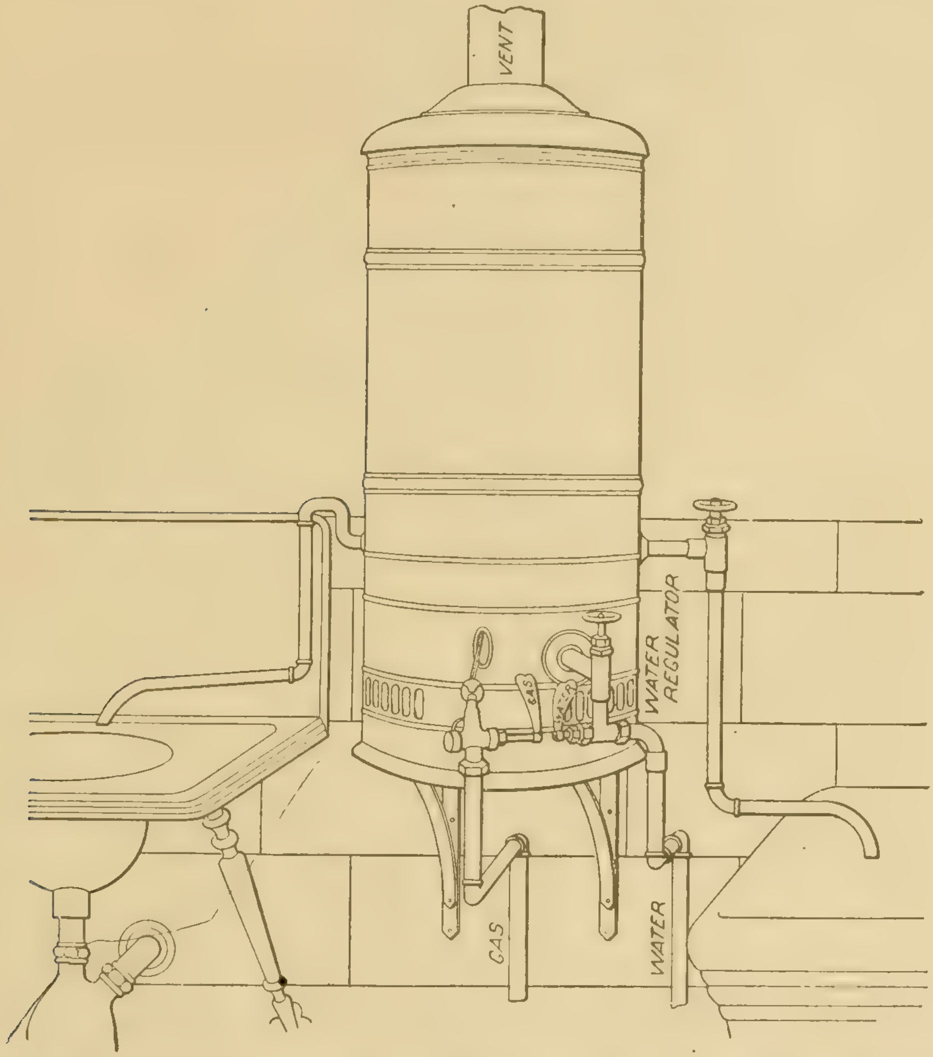


Fig. 92. "Instantaneous" Heater Connected to Gas Supply Pipe. Gasoline is Sometimes Used instead of Gas.

in Fig. 91. It consists of a chamber surrounded by an outer jacket with an air-space between. Circulation pipes, through which the water passes, are hung in the inner chamber, just above a powerful gas-burner placed at the bottom of the heater. Drawing water from the hot faucets lowers the temperature in the reservoir through the cooling influence of the incoming water, and the thermostatic principle is again made to serve in opening the gas-valve until the water is heated to the desired temperature.

There are other arrangements consisting essentially of an encased copper coil, above a gas-burner, connected to a standard reservoir at top and bottom. In these, the gas is turned on and regulated by hand as nearly as possible to suit the needs.

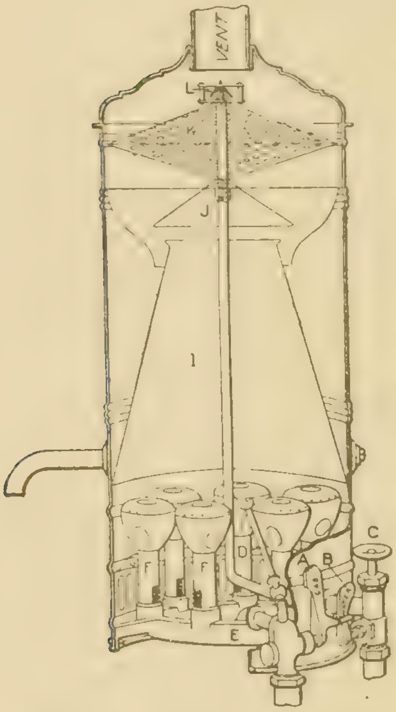


Fig. 93. Sectional View of Gas Heater Shown in Fig. 92.

Instantaneous water-heaters, operated by gas or gasoline, and placed in proximity to the fixtures served, as shown in Fig. 92, so as to deliver the heated water directly, are in general use where local conditions favor them. These have no storage capacity. A sectional view of Fig. 92 is shown in Fig. 93, in which *A* is the gas-valve; *B*, the water-valve; *D*, the pilot light; *FF*, the burners; *I*, a conical heating ring; *J*, a disc to retard and spread the rising heat; *K*, a perforated copper screen; and *L*, a revolving water distributer. In this heater, the water is exposed directly to the heated air and gases, in addition to its passing over the heated surface of the ring *I*.

Other heaters of this class offer admirable means for the water to take up the heat generated by the gas. All of these special means of heating water—especially those not conforming to the plumber's regular routine—are best understood and judged by a close study of the literature supplied by the makers.

FILTERS

Filters are of two classes. One class is designed to be attached to the end of the faucet or to special connection for drawing directly for use. The other is for use in the general house service, and filters all the water that passes through the main service for whatever purpose. In the former class, sand, free stone, or unglazed potter's clay is used as the filtering medium. Ordinary fillings become foul throughout the mass, and require cleansing or renewing. The clay (unglazed porcelain) of which the Pasteur filter is an example, permits nothing to enter the filtering medium that the pores of this material will strip out. With such, therefore, it is necessary only to remove the tubes and cleanse the surface with which the unfiltered water comes in contact. Any porous filter plate depends for its efficiency upon the minuteness of the pores through which the water passes; and there is a real danger that after a prolonged period of use, these pores may become enlarged by wear from the flowing stream to a size sufficient to allow the passage of bacteria which at the first would have been retained upon the surface of the filter plate. Porous clay filters, however, are exceedingly slow in operation; and it is necessary to employ a multiplicity of tubes, and to collect the filtered water in a reservoir, in order to be able to get enough at once to serve ordinary cooking needs. The filters are supplied with as many tubes as desired, together with the necessary reservoir, all complete excepting connections for the water pipe.

Large filters for service interposition depend upon animal charcoal, beach sand, and coagulating processes—usually the last-mentioned feature in conjunction with one of the other two. A sand filter, for instance, will be made to favor the subsidence of foreign material by the water taking an upward course through the mass of filling, a portion of the water being passed through an alum chamber so as to impregnate the supply sufficient to coagulate impurities which sand alone would allow to pass. When dissolved and carried away, the alum must be replaced. The filling is discarded and new sand put in its place from time to time; and periodic cleansing of the filling is done by reversing the flow of water and flushing out through a waste connection at the bottom. The means of thus keeping the filter in good order are provided for in its construction, in a way to make the cleansing and renewing of the material as easy and convenient as possible.

GAS PIPING

The work of piping for gas is so closely allied to that of plumbing, since iron pipe has come into general use, that a brief notice of this branch is not out of place in connection with matters pertaining to plumbing. Coal gas is only about one-half the specific weight of air. The weight of natural gas is somewhat less than that of coal gas. The distribution of pressures which prevails in a closed system—the pressure of the fluid being equal at every point—should not be lost sight of in considering the ordinary method of distributing gas over a city or through a building in closed pipes. Although it would be true that in an open vessel the pressure of illuminating gas would by reason of its low specific gravity be greater at the top of the vessel than at the bottom, this is not the case in a closed system in which a fixed pressure is maintained.

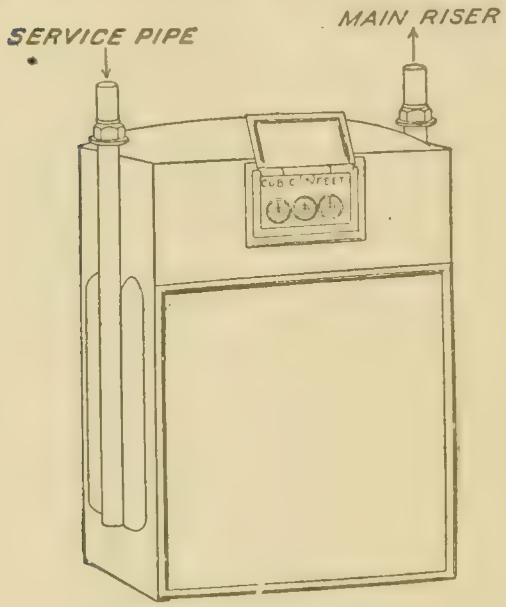


Fig. 99. "Dry" Gas Meter.

The most economical pressure at which to consume gas is five-tenths of an inch water pressure. As no town is strictly level, and the friction of the pipe requires some head of pressure to overcome it, the pressure in the mains is carried above the point at which the best results are obtained. This is generally counteracted by not turning on the full amount at the burner. In towns varying greatly in the level of different portions, it is economy to use an automatic governor to reduce the pressure. This is true of exceedingly tall buildings, too. But in the tall building, one governor for the whole is not enough; the supply to the upper floors should be controlled by a governor situated on one of the upper floors.

Large pipe should not be notched into joists in the middle of their length; it weakens the joists. All pipes should be laid with a decline, toward the meter when possible, otherwise in such a way that they will drain toward a fixture or drip. The meter should be placed in a position easily accessible, and where it may be read without the use of an artificial light. It is connected in the house main on the street side of the first branch. A *dry* meter—the kind now almost universally employed—is shown in Fig. 99.

Different meters vary but little in the arrangement of the dials. In large meters, there are as many as five or more dials; but those used for dwelling houses usually have but three. Fig. 100 shows the common form of index in a dry meter. The small index hand *D*, on the upper dial, is not taken into consideration when reading the meter, but is used merely for testing. The three dials, which record the consumption of gas, are marked *A*, *B*, and *C*; and in each, a complete revolution of the index hand denotes 1,000, 10,000, and 100,000 cubic feet, respectively. The index hands do not move in the same direction. When the hands are pointing upward, *A* and *C* move from left to right, while *B* moves in the opposite direction. Annex two cyphers at the right of the figures indicated when taking the statement of a meter. The left-hand index shown in Fig 100 reads 48,700. Suppose, after being used for a time, the hands should have the positions shown in the right-hand dial. This would read 64,900; and the amount of gas used during the interval would equal the difference in the readings: 64,900 — 48,700 = 16,200 cubic feet. Meters so invariably register in favor of the consumer after being in use only a few weeks, that the companies are by law permitted to set them 2 per cent fast when new.

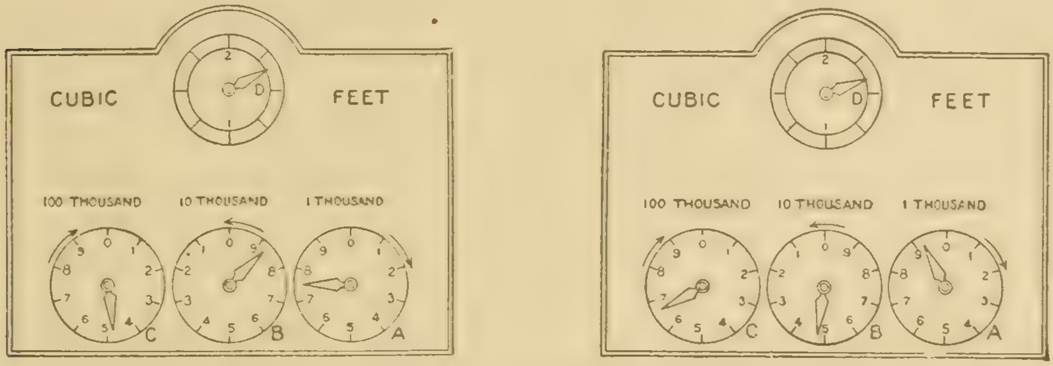


Fig. 100. Common Form of Index on "Dry" Gas Meter. Two Readings are Shown.

The route chosen for gas pipes should be the warmest consistent with convenience and economy. Coal gas will freeze—that is, the moisture in it will, in severe weather, form a network of frost that checks or stops the flow. Coal gas and natural gas are practically fixed. There is little trouble from condensation, even from coal gas, after it reaches the residence. There is sufficient reason, however, to incline the pipe and to avoid trapping any portion so that it will not drain. If a pipe runs through a cold place, a drip should be put in at some convenient point where it can be emptied if necessary. No offsets should be made in a way to favor choking the pipe by the products of corrosion falling down vertical parts. No fixture or bracket opening should be less than $\frac{3}{8}$-inch; no rising main less than $\frac{3}{4}$-inch. All openings for fixtures should have straight threads, and the pipe or fittings should be well secured, perpendicular to the wall passed through, so that they will not wobble, push in, or pull out. Ceiling drops should be cemented in the joint at the line, so that they will not unscrew when the cap is removed or a fixture taken down.

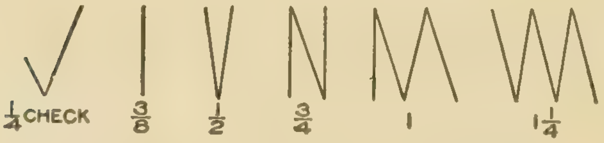


Fig. 101. Symbols Used in Piping Diagrams.

The making of intelligent working diagrams for gas or water fitting, is not difficult. Though important, comparatively few have given it due attention. When plans are accurate, the usual work of making figures to show what length the pipes are, may be dispensed with by employing self-measuring ruled sheets in conjunction with the method of diagramming here described. Diagramming systematically and with all lines approximately proportional in length, saves time in distributing the pipe. There is no wondering whether a piece runs down or up, or as to which room a bracket light looks into, or whether a piece of pipe belongs in a horizontal or in a vertical position. A properly made diagram indicates these points clearly, and also what pieces belong in the same plane. There should never be any confusion as to which pieces have been cut and which not, when getting out the pipe. Symbols can be made to show what pieces have been cut and what size they are. The symbols found by practice to answer this purpose best, are as follows: When a $\frac{1}{4}$-inch piece is cut, a common check mark is put *beside* the line on the diagram, showing that it is $\frac{1}{4}$ inch and has been cut. For a $\frac{3}{8}$-inch piece, a short, straight mark like the letter I, placed *across* the line, is used. For a $\frac{1}{2}$-inch piece, two connected marks like V are made *across* the line. For $\frac{3}{4}$-inch pieces, three connected marks, like the capital N, are made *across* the line. For 1-inch pieces, four connected marks, like the capital letter M, are used *across* the line. For $1\frac{1}{4}$-inch pieces, five connected marks, like the capital W with one extra leg, are used. Each short, straight mark represents a quarter-inch in the diameter of the pipe, except in the case of ⅜-inch pipe. For nipples that are too short to put the symbols on, draw a waved arrow from the nipple, and put the symbol upon it. Fig. 101 shows the symbols described, with corresponding sizes of pipe marked beneath them.

In reading plans of buildings, it is usual to have the front of the building, as represented by the plans, next to the person. Plans represent horizontal sections at the elevations designated; while elevations show the altitude of one floor above the other, etc. The plans of the different floors of a building are usually drawn side by side, with the outside face of the front wall on a line. By this means, a straight edge laid across the plans from side to side, will show which partitions are in line with one another. One can judge with the eye, on the cross-partitions, accurately enough to give a good idea of the relative position of the rooms on different floors, one way; but to locate the partitions running from front to back, it is necessary to measure from the wall on the plans of the different floors. House plans are almost always drawn to ¼-inch scale. In gasfitting diagrams, all sizes of pipe are represented by single or skeleton lines, because the pipes are small.

Now, assuming the plans to be marked for gas, center the rooms, and chalk all wall openings. Then proceed to diagram the lines representing the pipe, making them as nearly proportional to the length of pipe as can easily be done with pocket-rule and pencil, say to ¼-inch scale.

Represent all vertical pipes by diagonal lines parallel to one another, whether they be bracket pipes, risers, or offsets in the line. Never represent a horizontal pipe by a diagonal line. Every vertical pipe which *falls below* the horizontal pipe to which it is connected, should be drawn *toward the front* of the plan at an angle of 45 degrees to the *left*. Every vertical pipe which *rises above* the horizontal pipe to which it is connected, should be drawn *away from the front* of the plan, at an angle of 45 degrees to the *right*. Represent all horizontal pipes by parallel lines perpendicular either to front or to side wall. When the run of pipe is from front to back, the parallel lines should be perpendicular to the front wall of the building. When the run is from side to side, the parallel lines should be perpendicular to the side wall of the building. Any line in the diagram that is perpendicular to any other line of the diagram may then be taken to represent a horizontal pipe. Any number of lines representing horizontal pipe and all joined together, are thus indicated to be in the same horizontal plane. Any single line or system of lines representing horizontal pipe, but separated from the others by a diagonal line, is therefore in a different horizontal plane. For instance, the second-floor riser, 10 feet 3 inches long, shown in the diagram, Fig. 102, connects the horizontal pipe under the second floor with that under the third floor. These pipes are in different planes, one set being 10 feet 3 inches above the other.

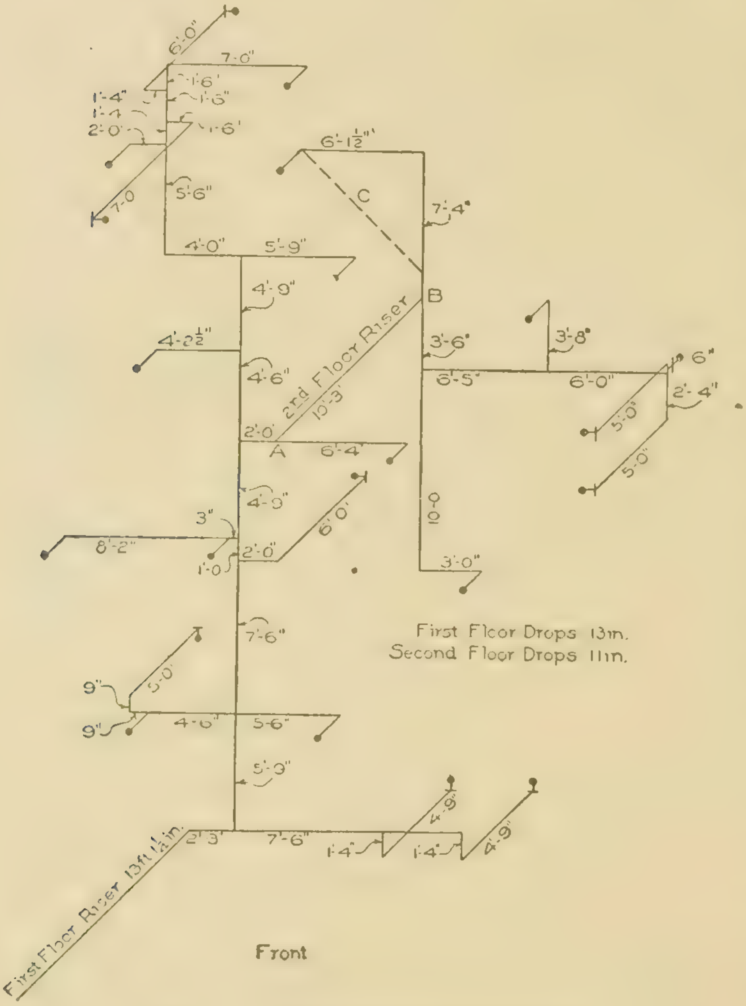


Fig. 102. Diagram of Gaspipe Lines.

There is one exception to the rule concerning diagonal lines. Several feet of pipe can often be saved by cutting across, instead of making an angle with, the pipe. To do this without danger of confusing one as to whether the diagonal piece is intended for vertical pipe or for a diagonal piece in the horizontal plane, make such lines *dotted* instead of *solid*, as shown at *C*, Fig. 102.

To indicate the direction in which bracket openings look, by the way in which they are drawn, eight skeleton diagrams of bracket pipes, showing how the direction of bracket openings would be indicated for the four walls of a square room, are shown in Fig. 103. *A*, *B*, *C*, and

D show that the pipes are vertical and run up from the floor below, *A* looking into the room from the front wall, *B* from the rear, *C* from the left side wall, and *D* from the right side wall. In accordance with plan drawing, the short lines representing the ears and nozzle of the drop-ells are made in plan position with dots at the ends to represent caps. The ears of the fitting, drawn in front of the outlet, show that the fitting looks to the rear; ears behind the outlet show that it looks to the front; at the left of it, that it looks to the right; and to the right of it, that the fitting looks to the left.

A^1, B^1, C^1, and D^1 show fittings that look in the same direction as those shown by *A*, *B*, *C*, *D* of the same figure, but are on pipes that run down from the horizontal pipe. By varying the positions of the marks representing the drop fittings to suit, the diagram can be made to indicate openings pointing in any direction desired.

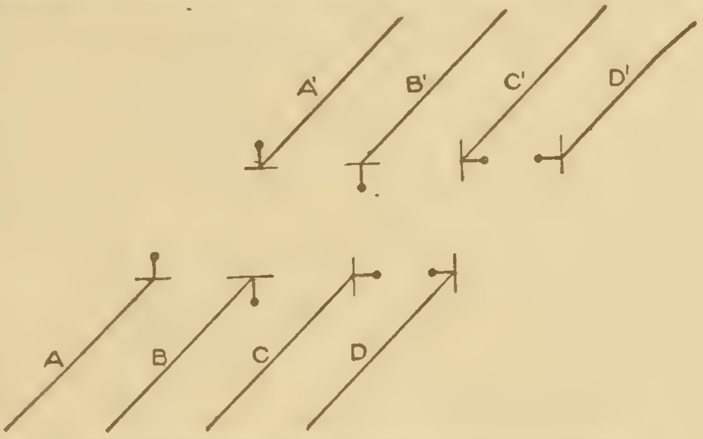


Fig. 103. Skeleton Diagrams of Bracket Pipes.

All large risers should be exposed to view; and it is desirable to keep all piping accessible as far as possible, so that it may be easily reached for repairs if necessary. When it is necessary to trap a pipe, a drip with a drain-cock must be put in; but this should always be avoided under floors or in other inaccessible places. Where possible, it is better to carry up a main riser near the center of the building, as the distributing pipes will then average smaller, the timbers will not require so much cutting, and the flow of gas will be more uniform throughout.

Unless otherwise directed, outlets for brackets should be placed 5$\frac{1}{2}$ feet from the floor, except in the case of hallways and bathrooms, where it is customary to place them 6 feet or more from the floor. Upright pipes should be plumb, so that nipples which project through the walls will be level; the nipples should not project more than $\frac{3}{4}$ inch from the face of the plastering. Laths and plaster together are usually about $\frac{3}{4}$ inch thick, so that the nipples should project about 1$\frac{1}{2}$ inches from the face of the studding. *Drop-* or *side-ells* are used where possible for bracket openings. Gas pipes should never be placed on the bottom of floor timbers that are to be lathed and plastered, because they are inaccessible in case of leakage or alterations. Fig. 104 illustrates some lines of gaspipe in a frame building, from which may be gleaned graphic ideas of how to fasten pipe securely in place.

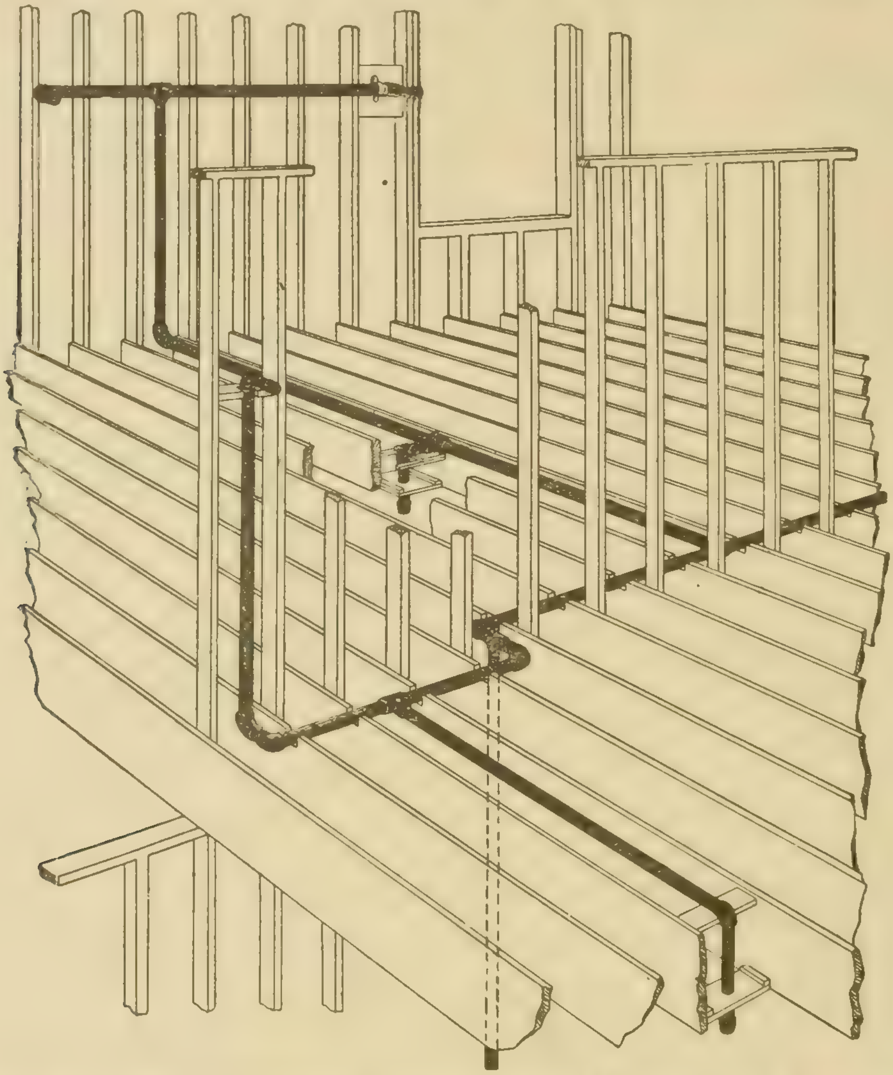


Fig. 104. Lines of Gaspipe in Frame Building, Showing How Pipes are Secured in Place.

Coal gas, and natural gas of some locations, has a strong odor that betrays leakage. Some natural gas is devoid of odor, in which case leakage is very dangerous, as there is no way quickly to detect its presence. For natural gas work, 10 pounds' air-pressure should fail to develop the slightest leak in the pipe, although the street pressure is usually even less than eight ounces. For lighting gas, the street pressure is seldom over 18 tenths water-pressure, and a 5-pound test is ample. These tests should be made with a mercury gauge, 2 inches height of column being considered as one pound pressure. A job may be considered tight when the mercury column not only does not drop, but does not even get flat at the top in from fifteen to twenty minutes' trial.

Every gas company has rules as to the number of lights allowed to be supplied from each size pipe, and the relative lengths of pipe permitted of each size. The following table gives sizes of gas pipes for different numbers of burners and lengths of runs, as usually installed:

TABLE IV

Maximum Run and Number of Burners for Gas Pipes

SIZE OF PIPE	GREATEST LENGTH OF RUN, FEET	GREATEST NUMBER OF BURNERS TO BE SUPPLIED
$\frac{3}{8}$ inch	20 feet	2
$\frac{1}{2}$ "	30 "	4
$\frac{3}{4}$ "	50 "	15
1 "	70 "	25
$1\frac{1}{4}$ inches	100 "	40
$1\frac{1}{2}$ "	150 "	70
2 "	200 "	140
$2\frac{1}{2}$ "	300 "	225
3 "	400 "	300
4 "	500 "	500

No restrictions are observed in selecting fixtures for coal or natural gas. Coal gas carries enough carbon with it to produce a lighting flame when burned at the ordinary flame temperature. When the jet is lighted, the hydrogen is consumed in the lower part of the flame, producing sufficient heat to render incandescent the minute particles of carbon carried by it. The hydrogen, in the process of combustion, combines with the oxygen of the air, forming an invisible vapor of water, while the carbon unites with the oxygen, forming carbonic acid, or is set free as soot.

Various causes tend to render combustion incomplete. There may be excessive pressure of gas, lack of air, or defective burners. An excess of pressure at the burners causes a reduction of the amount of illumination; on the other hand, if the pressure is insufficient, the heat of the flame will not raise the carbon to a white heat, and the result will be a smoky flame. It therefore follows that for every burner there is a certain pressure (usually $\frac{5}{10}$ of an inch water-pressure before mentioned) and a certain corresponding flow of gas, which will cause the brightest illumination.

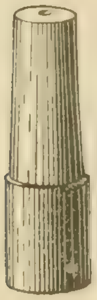


Fig. 105. Single-Jet Burner.

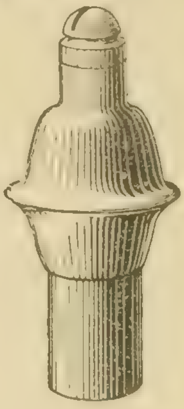


Fig. 106. Bat's-Wing or Slit Burner.

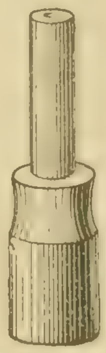


Fig. 107. Union-Jet or Fish-Tail Burner.

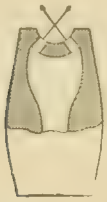


Fig. 108. Vertical Section of Union-Jet Burner.

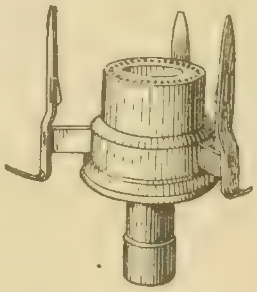


Fig. 109. Argand Burner.

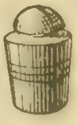


Fig. 110. Lava Tip for Bat's-Wing Burner.

There are a great variety of burners upon the market, among which the single-jet, bat's-wing, fish-tail, Argand, regenerative, and incandescent burners are the principal types.

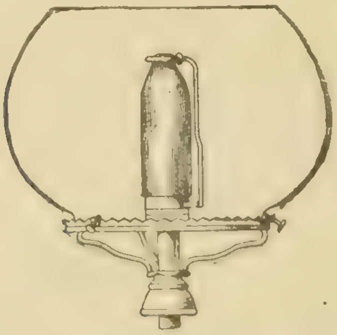


Fig. 111. Gas Burner with Globe and Incandescent Mantle.

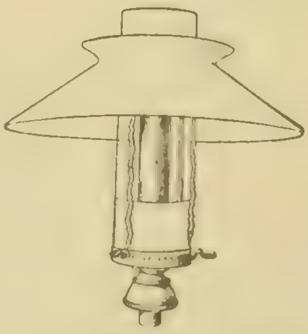


Fig. 112. Mantle Burner with Chimney and Shade.

The *single-jet* burner, Fig. 105, is the simplest kind, having but one small hole from which the gas issues. It is suitable only where a very small flame is required.

The *bat's-wing* or *slit* burner, Fig. 106, has a hemispherical tip with a narrow vertical slit from which the gas spreads out in a thin, flat sheet, giving a wide and rather low flame resembling in shape the wing of a bat, from which it is named.

The *union-jet* or *fish-tail* burner, Fig. 107, consists of a flat tip slightly depressed or concaved in the center, with two small holes drilled, as shown in Fig 108. Two jets of equal size issue from these holes, and, by impinging upon each other, produce, at right angles to the alignment of the holes, a flat flame longer and narrower in shape than the bat's-wing, and not unlike the tail of a fish. Neither of these burners requires a chimney, but the flames are usually encased with glass globes. They are not well suited for use with globes, however, since when one of the jets becomes choked, as it frequently does, the other is likely to crack the glass.

The *Argand* burner, Fig. 109, consists of a hollow ring of metal or lava, connected with the gas tube, and perforated on its upper surface with a series of fine holes, from which the gas issues, forming a round flame. This burner requires a glass or mica chimney. As an intense heat of combustion tends to increase the brilliancy of the flame, it is desirable that the burner tips shall be of a material that will cool the flame as little as possible. On this account, metal tips are inferior to those made of some non-conducting material, such as lava, adamant, enamel, etc. Metal tips are also objectionable because they corrode rapidly, and thus obstruct the passage of the gas. Fig. 110 shows a lava tip for a bat's-wing burner. Burner tips should be cleaned occasionally, but care should be taken not to enlarge the holes.

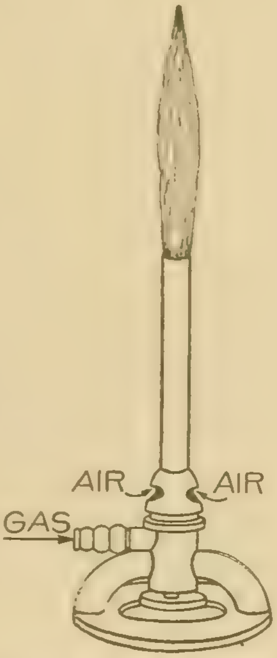


Fig. 113. A Bunsen Burner.

By introducing the Bunsen principle, *incandescent* burners give good service with coal gas. In the incandescent burner, the heat of the flame is applied in raising to incandescence some foreign material, such as a basket of magnesium or platinum wires, or a funnel-shaped asbestos wick, or a mantle treated with sulphate of zirconium and other chemical compounds. A burner of this kind is shown in Fig. 111, in which the mantle can be seen supported over the gas flame by a wire at the side. Fig. 112 shows another form of this burner, in which a chimney and shade are used in place of a globe. Burners of this kind give a very brilliant white light when used with natural or water gas. Natural gases and the so-called water gas are deficient in carbon; and, when they are used for lighting

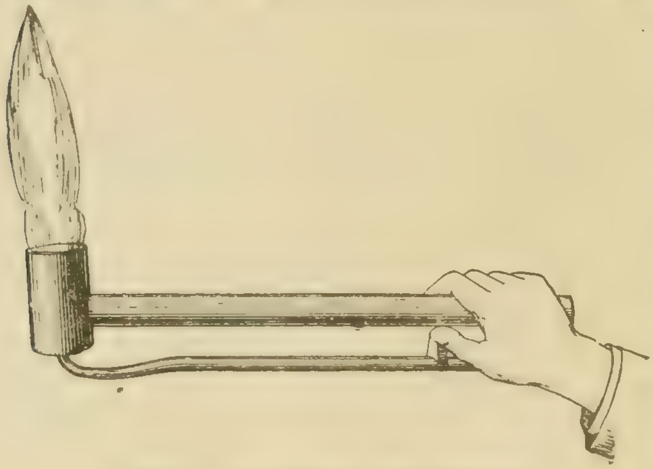


Fig. 114. Gas Burner for Brazing.

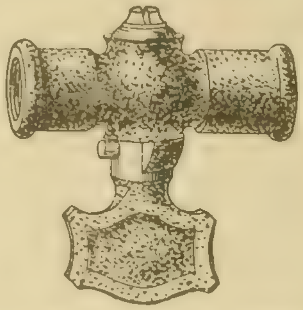


Fig. 115. Single Gas-Cock with Stop-Pin.

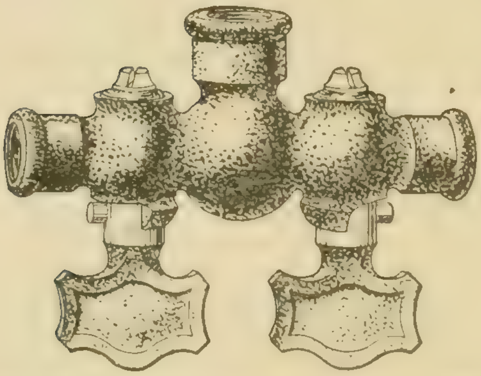


Fig. 116. Double Gas Cock with Stop-Pins.

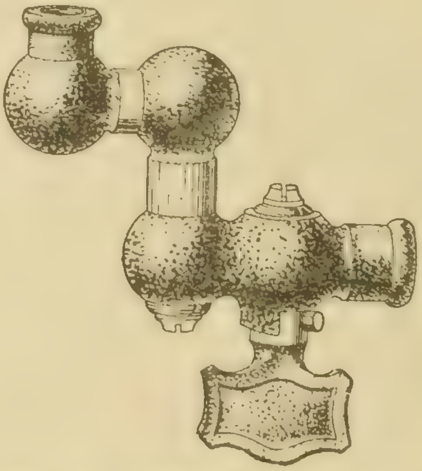


Fig. 117. Elbow Gas-Cock with Stop-Pin.

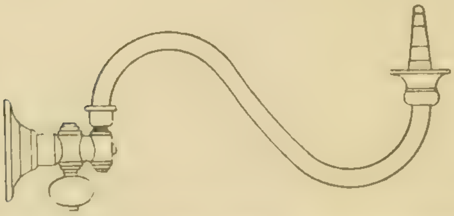


Fig. 118. Common Form of Gas Bracket.

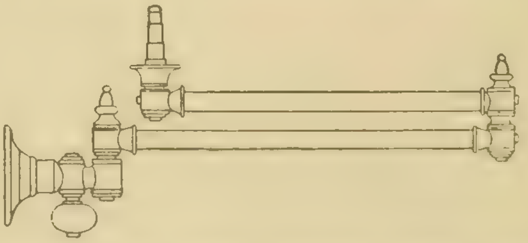


Fig. 119. Two-Swing Extension Gas-Bracket.

purposes, the light is produced by a burner with a mantle brought to a state of incandescence by the heat of the flame. The mantle, however, is very fragile, and is likely to lose its property of incandescence when exposed to an atmosphere containing much dust.

The *Bunsen burner*, shown in Fig. 113, is a form much used for laboratory work. It burns with a bluish flame, and gives an intense heat without smoke or soot. The gas, before ignition, is mixed with a certain quantity of air, the proportions of gas and air being regulated by the thumb-screw at the bottom, and by screwing the outer tube up or down, thus admitting a greater or less quantity of air at the openings indicated by the arrows. This same principle is utilized in a burner for brazing, the general form of which is shown in Fig. 114. A flame of this kind will easily melt brass in the open air.

It is of great importance that gas keys on fixtures should be perfectly tight. It is rare to find a house piped for gas where the pressure test could be successfully applied without first removing the fixtures, as the joints of folding brackets, extension pendants, stop-cocks, etc., are usually found to leak more than the piping. The old-fashioned all-around cock without check-pin should never be allowed under any conditions; only those provided with stop-pins are safe. Various forms of cocks with stop-pins are shown in Figs. 115, 116, and 117. All key joints should be examined and tightened up occasionally to prevent them becoming seriously loose and leaky.

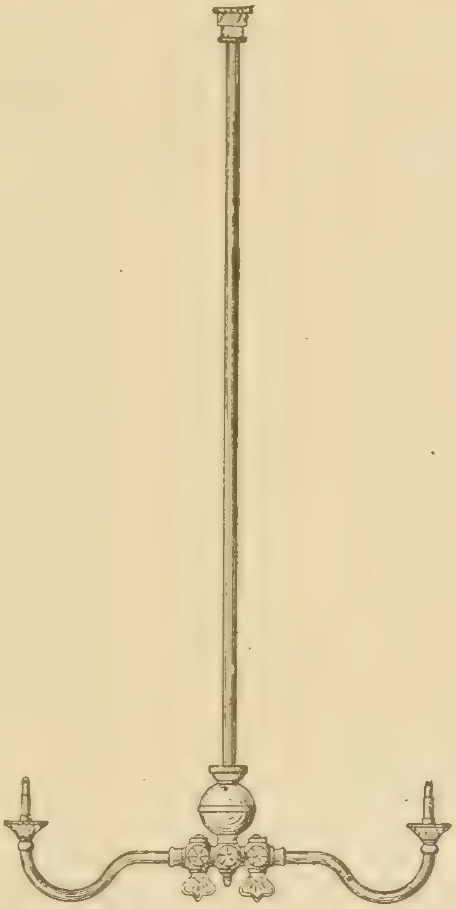


Fig. 120. Plain Type of Two-Burner Gasolier.

Poor illumination is frequently caused by ill-designed or poorly constructed brackets or gasoliers. Gas fixtures, almost without exception, are designed solely from an artistic standpoint, without due regard to the proper conditions for obtaining the best illumination.

Fixtures having too many scrolls or spirals may, in the case of imperfectly purified gas, accumulate a large amount of a tarry deposit, which, in time, hardens and obstructs the passages. Another fault is the use of very small tubing for the fixtures. Common forms of brackets are shown in Figs. 118 and 119, the latter being a *two-swing extension bracket.*

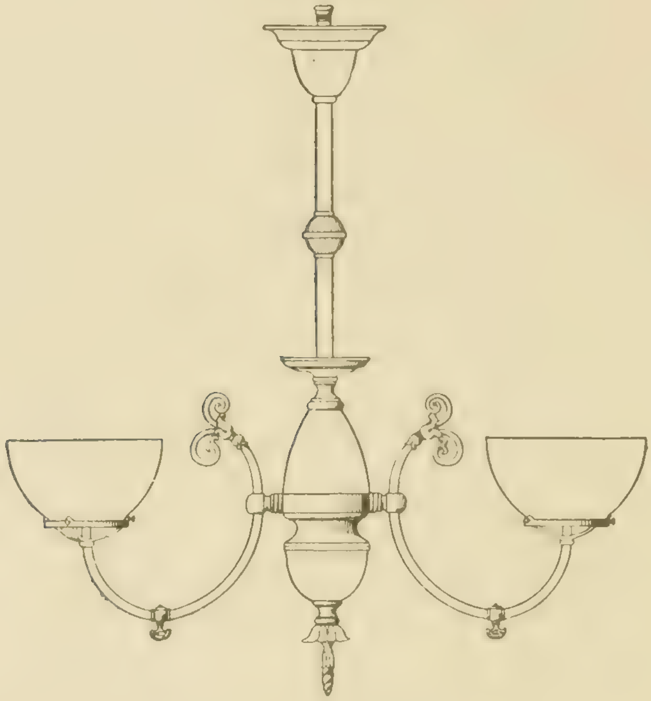


Fig. 121. Ornamental Type of Two-Burner Gasolier.

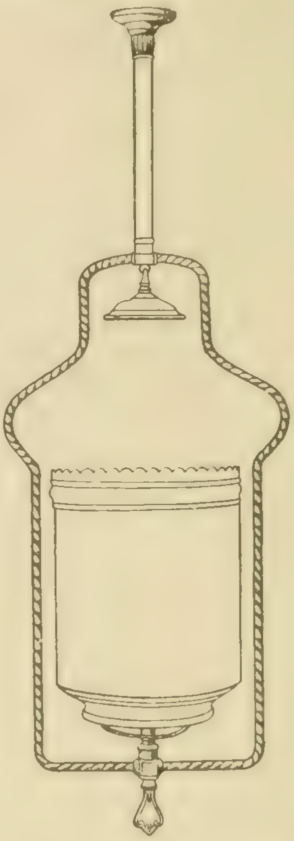


Fig. 122. Gasolier for Hall or Corridor.

There are an endless variety of gasoliers used, depending upon the kind of building, the finish of the room, and the number of lights required. Figs. 120, 121, and 122 show common forms for dwelling houses the type shown in Fig. 122 being used for halls and corridors.

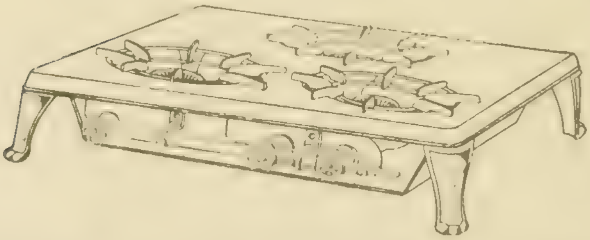


Fig. 123. Simple Form of Gas Plate with Three Burners.

Next to the burner, the shape of the globe or shade surrounding the flame affects the illuminating power of the light. In order to obtain the best results, the flow of air to the flame must be steady and uniform. Where the air supply is insufficient, the flame is likely to smoke; on the other hand, too strong a current of air causes the light to flicker and become dim through cooling.

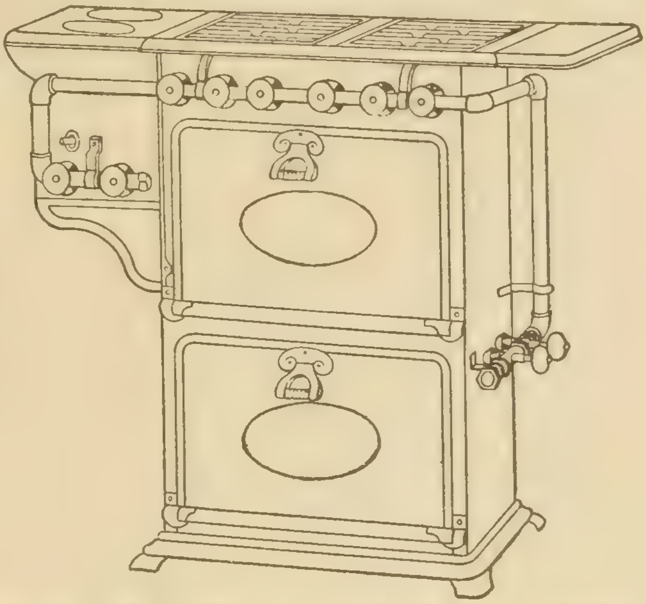


Fig. 124. Gas Range for Family Use, with Ovens and Water-Heater.

Globes with openings too small at the bottom, should not be used. Four inches at the bottom should be the smallest opening used for an ordinary size burner. All glass globes absorb more or less light, the loss varying from 10 per cent for clear glass, to 70 per cent or more for opal, ground, colored, or painted globes. Clear glass is therefore much more economical, although, where softness of light is especially desired, the use of opal or ground globes is made necessary.

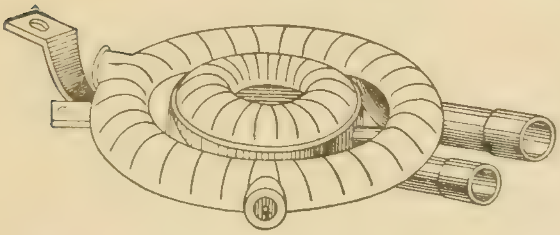


Fig. 125. Griddle Burner for Gas Range.

Cooking as well as heating by gas is now very common, and there are a great variety of appliances for the use of gas in this way. Cooking by gas is not more expensive, and is less troublesome, than by coal, oil, or wood. It is also more healthful, on account of the absence of waste heat, smoke, and dust. A gas range is always ready for use, and is instantly lighted by applying a match to the burner. The fire, when kindled, is at once capable of doing its full work; it is easily regulated, and can be shut off the moment one is through with it, so that, if properly managed, there is no waste as is the case with other fuel. With gas, the kitchen can be kept comparatively cool and comfortable in summer.

Fig. 126. Oven Burner for Gas Range.

Gas stoves are made in all sizes, from the simple form shown in Fig. 123, to the most elaborate range for hotel use. A range for family use, with ovens and water-heater, is shown in Fig. 124. Figs. 125 and 126 show the forms of burners used for cooking, the former being a *griddle burner,* and the latter an *oven burner.*

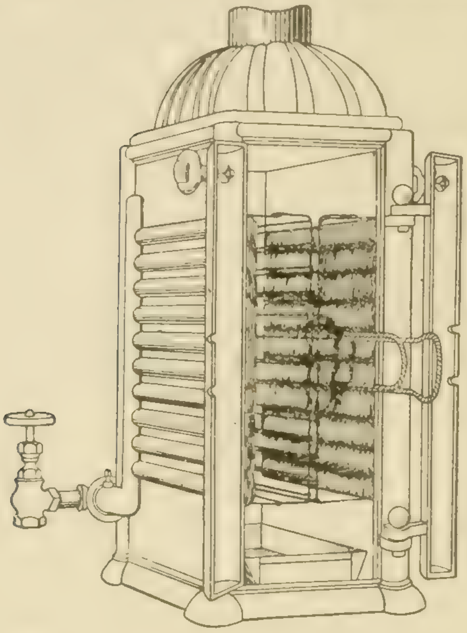


Fig. 127. Gas Broiler, Asbestos-Lined.

A *broiler* is shown in Fig. 127; the sides are lined with asbestos, and the gas is introduced through a large number of small openings. The asbestos becomes heated, and the effect is about the same as a charcoal fire upon both sides.

Gas as a fuel has not been used to any great extent for the warming of whole buildings, its application being usually confined to the heating of single rooms. Unlike cooking by gas, a gas fire for heating is not

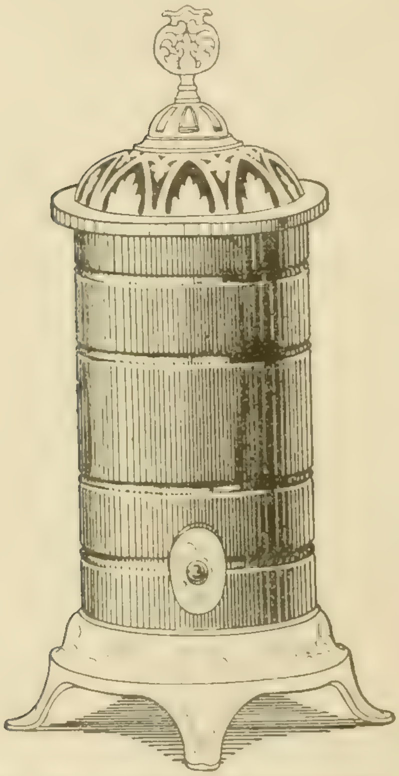


Fig. 128. Common Form of Portable Heater, Connected by Rubber Tubing to Gas-Jet.

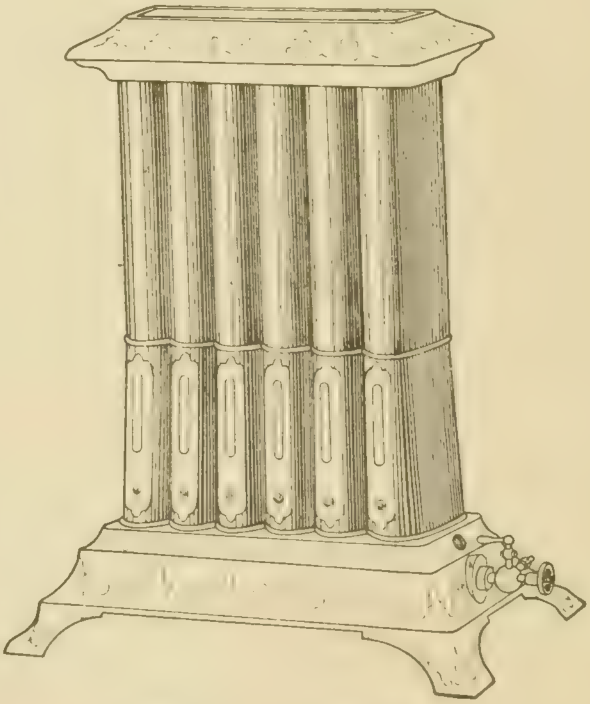


Fig. 129. Gas Radiator.

so cheap as a coal fire when kept burning constantly. In other ways it is effective and convenient. It is especially adapted to the warming of small apartments and single rooms where heat is wanted only occasionally and for brief periods of time. In the case of bedrooms, bathrooms, or dressing-rooms, a gas fire is preferable to other modes of warming, and is fully as economical. It may be used on cold winter days as a supplementary source of heat in houses heated by stoves or by furnaces. Again, a gas fire may be used as a substitute for the regular heating apparatus in a house, in the spring or fall, when the fire in the furnace or boiler has not yet been started. It is often employed as the only means for heating smaller bedrooms, guest rooms, and bathrooms, and for temporary heating in summer hotels where fires are required only on occasional cold days. Any con-

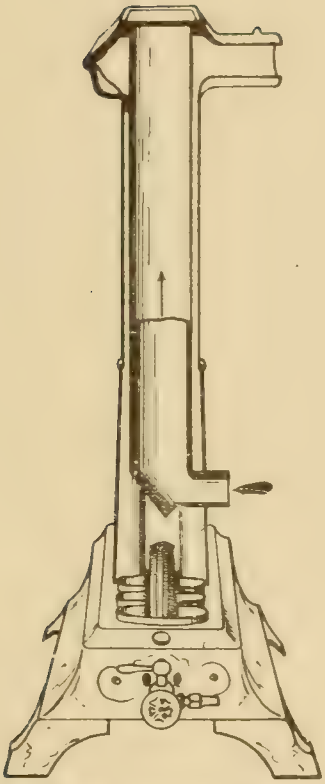


Fig. 130. Section of Gas Radiator of Fig. 129. Showing Flue to Connect to Chimney.

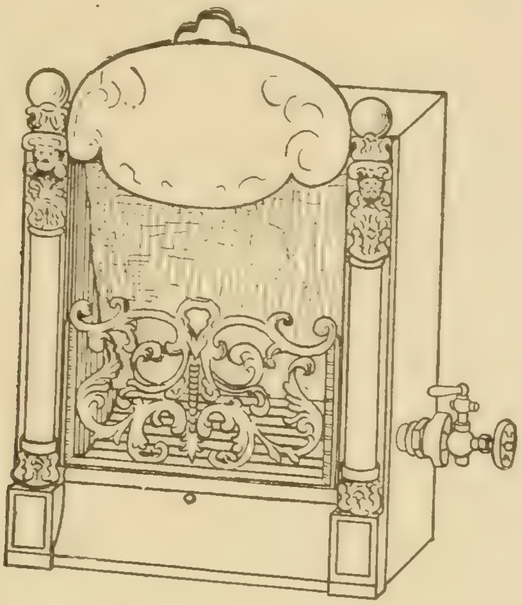


Fig. 131. Asbestos Incandescent Grate,

Fig. 132. Gas Log of Metal or Terra-Cotta and Asbestos.

siderable use of gas for heating necessitates the use of evaporators to maintain the normal humidity of the air.

The most common form of heater is that shown in Fig. 128. This is easily carried from room to room, and may be connected with a gas-jet by means of rubber tubing, after removing the tip. The heater is merely a large burner surrounded by a sheet-iron jacket. Another and more powerful gas heater is the *radiator*, shown in Fig. 129. This is fitted with a flue to conduct the products of combustion into the chimney, as shown in the section, Fig. 130. Each section of the radiator consists of an outer and an inner tube, with the gas flame between the two. This space is connected with the flue, while the air to be heated is drawn up through the inner tube, as shown by the arrows.

Fig. 131 shows an *asbestos incandescent grate*; and Fig. 132, a *gas log* of metal or terra-cotta and asbestos, made in imitation of a wood log or heap of logs. The gas issues through small openings in the logs, and gives the appearance of an open wood fire.

Fuel gas or *water gas*, largely made to supplement failing supplies of natural gas, is used for lighting in the same manner as natural gas. It is, in fact, but an impure commercial hydrogen made by injecting steam into hot coke. The oxygen of the steam combines with the carbon of the coke, and sets free the hydrogen, which is collected in a gasometer, ready for the distributing pipes. The prime use of this and of natural gases is for heating; but, by purifying it and supplementing it with carbon by incorporating with it vapors of petroleum, fuel gas makes rich and quite stable lighting gas.

PLUMBING

PART III

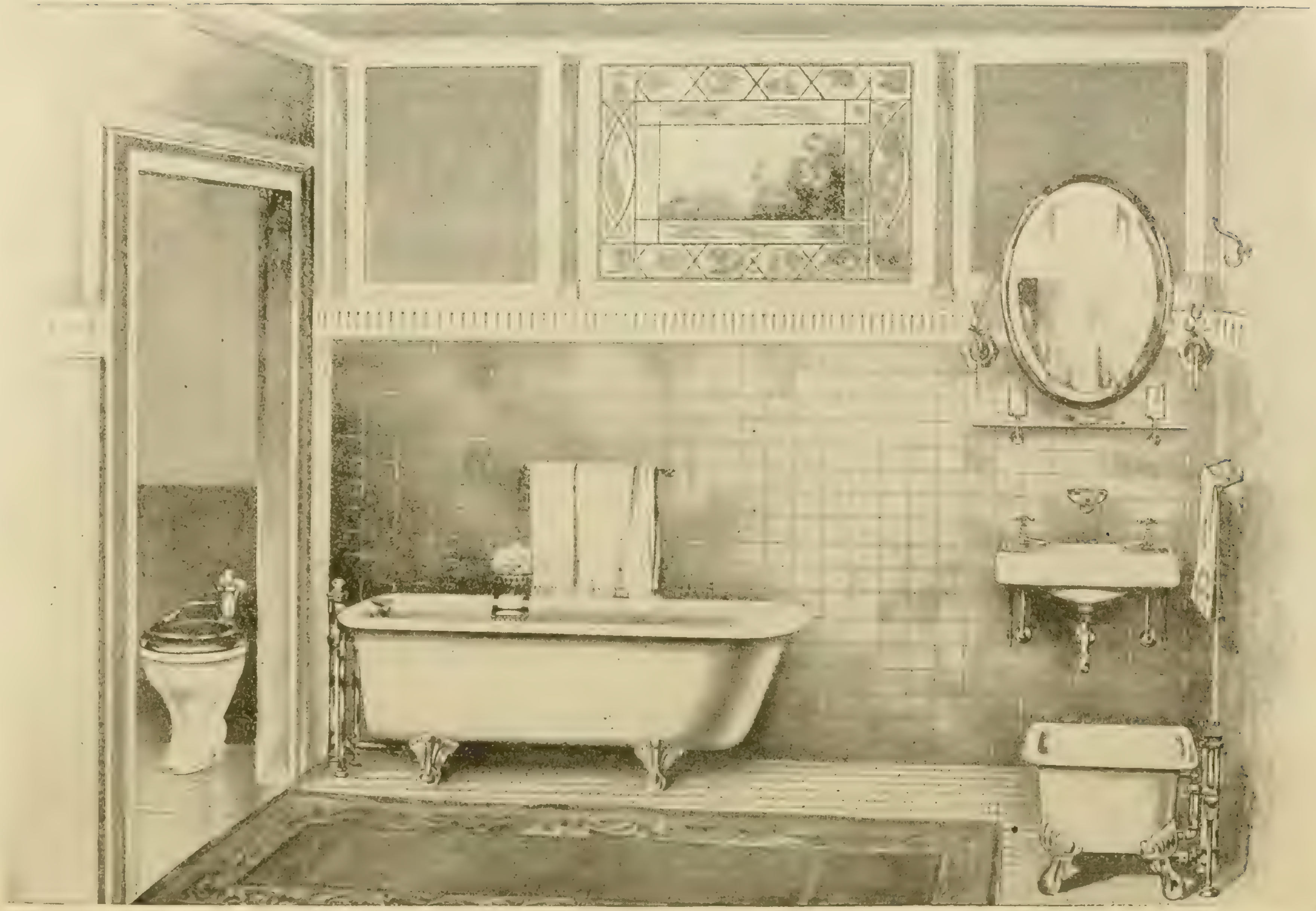
THE HOUSE DRAINAGE SYSTEM

Assuming that the method of disposing of sewage and drainage is decided upon, the problem of how to pipe the house safely may be considered as presenting about the same conditions, whether the house drain enters a branch from the city sewer or terminates in some other means of disposal.

Granted that sewer air is a thing to be guarded against, the safest plan is to pursue that course which offers the surest means of keeping the house free of it. We know that through contamination of water supply by filtration from vaults, etc., the human system may suffer pollution, and may develop specific disease of a serious, even fatal nature. It is no less certain that polluted air will affect the lungs similarly, according to the nature of the pollution. On this ground, notwithstanding any argument to the contrary, we should proceed to exclude sewer air entirely, and to make the air of the house drain-pipes as pure as possible.

It must be remembered that where a whole system of plumbing i designed with certain ends in view, and all the details worked out accordingly, a house system may be satisfactory which under slight disturbance of conditions would be abominable. Therefore no departure from a certain means of positively accomplishing a desired result should be accepted without unanimous endorsement of those in position to know what is safe. People, however, have been at all times too ready to accept any plan that promised the immediate saving of a dollar. Certain plumbing accessories may be admirably adapted to use in one place, yet wholly unfit for service in another; but the makers cannot be expected to discriminate; they are prejudiced, and are not on the ground. It is the business of the public, through architects and plumbers, to select suitable means to the end.

With the fresh-air inlet and proper installation throughout the building, an intercepting trap is likely to exclude sewer air from the



TYPE OF MODERN AMERICAN BATH ROOM WITH LATEST APPROVED FITTINGS.

The Federal Company.

house, and to keep the drains in the house filled with fresh air from the open atmosphere (see page 117). With these conditions, a possible leaky joint or defective trap can permit only comparatively pure air to enter from the pipe. The intercepting trap being in the main line, all water from the house passes through it, insuring the water seal being maintained. The foul-air outlet ventilates the sewer much as would the house lines if the trap were omitted, because in it there is never any contrary rush of air or water, both of which would check or reverse the current, and the latter of which reduces the area of the pipe, even though it be assumed that no further interference occurs through discharge from fixtures. The trap may be in the yard or within the house walls, according to circumstances. Fig. 142 shows an intercepting trap in the cellar, with its fresh-air inlet terminating above the snow-level. Many jobs were formerly piped in a way permitting soil air to puff out through the inlet. Fig. 143 shows a plan that has been resorted to with the idea of carrying such discharges to a safe height without interfering with the normal action of the fresh-air inlet. It is merely a rising line with an inverted funnel over the open end of the inlet, which incidentally protects the air-pipe from lodgment of foreign matter. The foul-air outlet should not terminate near a window or

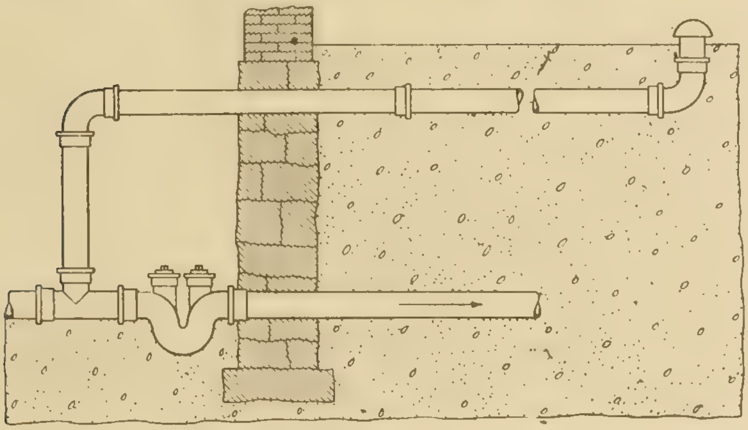


Fig. 142. Intercepting Trap in Cellar.

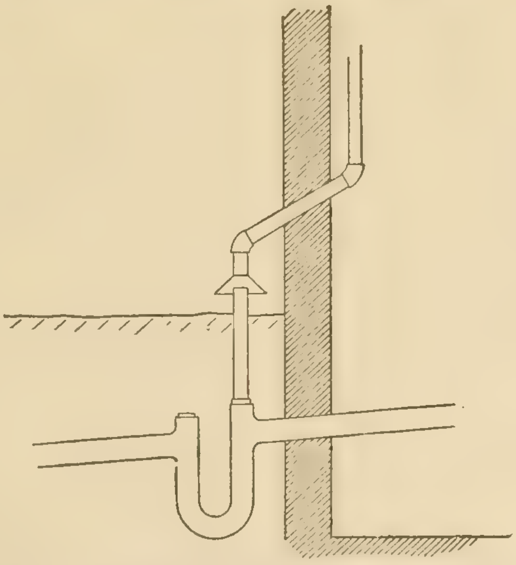


Fig. 143. Simple Device for Carrying Away to a Safe Height Soil Air that may be Puffed from Fresh-Air Inlet.

door, nor be too close to the fresh-air inlet opening. It should be located so that it will be free of chance obstruction, and above the level of winter ice and snow, even though it has to be piped to above the roof-level as indicated in Fig. 144, in which *A* is a cone strainer with solid top, and *T* the main intercepting trap. The direct line of foul-air pipe to roof, and the distance between the trap and fresh-air inlet grating, provide every requisite possible to this part of the house drainage, whether a *loop stack*, spoken of on another page, is employed or not.

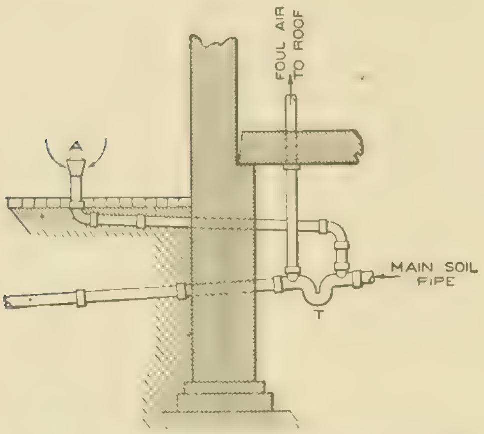


Fig. 144. Foul-Air Outlet from Intercepting Trap Carried to Roof.

A very good plan of terminating air inlet and outlet pipes in situations exposed to the entrance of obstacles, is to use a single or double hub return bend above snow-level, as shown in Fig. 145. In this way, nothing can fall in by accident; sleet from any direction cannot choke the openings; nor are children likely to fill the pipe.

Fig. 146 illustrates a galvanized-wire guard placed in the hub; such a guard is generally used on conductor pipe, but is equally suited to the protection of soil and vent lines in mild climates. In Northern localities, the regular cast hood and thimble made for the purpose are better. The area of the openings of the strainer should aggregate at least 12 square inches for pipe 4-inch or less; and where frost trouble is feared, the strainer should be recessed several inches so that the frost will have to close the open end of the pipe instead of the grating.

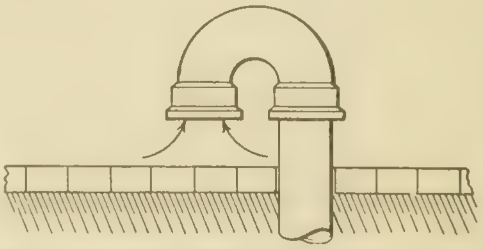


Fig. 145. Return Bend Used to Terminate Air Inlet or Outlet Pipe.

The foul-air pipe should not have abrupt offsets at any point. The lodgment of foreign matter therein would be possible, and the function of the pipe perhaps thus impaired. This pipe not only ventilates the sewer, but offers egress for air when storm water is crowding the sewer, and at other times when air-pressure would otherwise drive the seal of the trap toward the house, enough ultimately, in some cases, to lose the seal by waving out when the pressure is relieved.

When a trap loses its seal by waving out, the water, in flowing back to its normal position, gains momentum enough to throw some of it over the weir, and the balance is not enough to seal the trap. Waving out is always caused, first, by air-pressure on the sewer side, and then by gravity acting as described.

The operation of the fresh-air inlet depends on air from the open entering the house drain near the trap and filling the house system, passing out through the vent pipe above the roof. The inlet should be as large as the house sewer, which should never be less than 4 inches diameter, usually 5 inches. The same precautions taken against snow and ice and other obstructions to the foul-air outlet, are necessary to the fresh-air inlet. The difference in level of the inlet and the exit, together with the warmth of the building, causes an upward current through the stack. Even the taking a more exposed course and stopping at an elevation inferior to the outlet of the soil-pipe extension, when necessary to carry the inlet to the roof, will usually insure a draft.

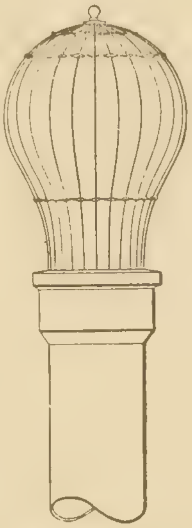


Fig. 146.
Galvanized-Wire Guard at End of Pipe.

Objection is often raised against the fresh-air inlet, for the reason that puffs of foul air are thrown out when fixtures are discharged. This is easily possible, but mainly the result of faulty installation. One feature of plumbing is no more likely to be satisfactory than another where ignorance prevails, or when merely the simple letter instead of the spirit of ordinary specifications is lived up to. House main lines of the same size as soil-stacks (4-inch) will cause puffs of air from the fresh-air inlet if the horizontal run and the inlet branch are both short. It is well to remember that the air so puffed out is not sewer air. It is air which has just entered the house system from the open. And, if the fresh-air branch is of decent length, as described, and as shown in Fig. 144, the puff occasioned by the discharge of a fixture in an ordinary house, even in an objectionable job, may not equal a third of the really fresh air in the inlet branch.

The chance of puffing under the action of fixtures can be avoided by a loop providing for simple revolution of air when fixtures are discharged. A soil-stack from the main horizontal line is carried up to the roof, with all connections as usual, except one. This is made above the highest fixture, and of the same size as the soil-stack, and is generally carried down and connected, as it should be, into the horizontal main several feet nearer the intercepting trap than where the corresponding soil-stack leaves the main. Some connections are so close to the point of exit that the vertical stacks are made to constitute the whole loop, as shown in Fig. 147, in which cases the direct stack *E* from *X* to *Y* should invariably be a portion of the vent. If the connection *X* is made in the horizontal run, as before mentioned, stack *F* should be the vent, as a rule, instead of carrying the closet branches *GG* as shown. *V* and *V* are crown vents for the closets. The crown vents may in some situations be made into a separate smaller line leading into the soil-stack above the highest fixture.

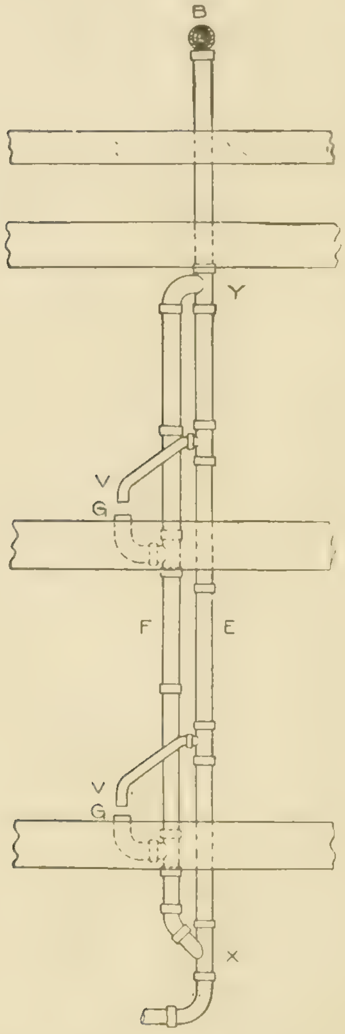


Fig. 147. Loops in Soil-Stack to Prevent Puffs of Air at Fresh-Air Inlet.

By the *loop* plan, air is thrust before the water discharged from a fixture as usual; also, there is the same tendency to a vacuum behind the water so discharged. But, instead of reversing the general current and drawing air from the roof to fill the void, the roof current in the soil-stack from the loop connection up, is merely checked, more or less; and the air already rising in the loop turns down the soil-stack and fills the void. Without the loop, considerable compression would take place in front of the water before the current in the house main could be reversed. With the loop, this compression is confined principally to the stack. The void being supplied by the loop, the air driven in front of the water simply passes up the loop in response to the call for air to fill the void behind the water.

Referring again to Fig. 147, air takes the course offering the least friction; and *F* branching out of and into *E*, which is the same size pipe as shown at *X* and *Y*, the greater part of a current of air passing upward through them will travel by pipe *E*. For this and other reasons it is best to take the branch pipe *F* for the soil pipe. Then, whatever offset may be necessary to reach the closet openings will be washed; and the straight, vertical stack left for the vent affords no chance for the lodgment of rust or other obstruction. When water is discharged into the soil pipe at *G*, pipe *Y* protects the closet trap from siphonage; and the tendency to form a vacuum above the water in the soil pipe by the piston action of the discharge water, is neutralized by a proportional draught of air from vent pipe *E* through branch *Y*. The air in the vent pipe between *Y* and *B* tends to continue its course to the roof, while that below the branch *Y* is traveling toward branch Y. A partial vacuum formed in soil pipe *F* by a discharge from a fixture, will be checked by a supply of air drawn from vent pipe *E* between branches *X* and *Y*. The vacuum formed behind the discharge water in soil pipe *F* increases the upward velocity of air in vent pipe *E* below *Y*; and the air pushed down in front of the discharge attempts to reverse the current below *X*. The increased velocity of the air in pipe *E* demands more air than was passing through it by natural draught. This demand is supplied by the extra volume which the water is pushing before it.

As long as the discharge water is above branch *X*, the air simply revolves in the two pipes which form the loop. The air in pipe *F* travels downward before the water, and up through pipe *E* and branch *Y*, and down pipe *F* behind the water. This revolution of air in the loop continues until the water reaches the junction *X* of pipes *E* and *F*, without causing any perceptible "puff" at the fresh-air inlet opening.

When both the connections are in vertical lines as in Fig. 147, after the water passes *X*, it will probably reverse the current of air in the fresh-air pipe in some instances; but, were it possible to shove out every atom of air in the soil pipe between the trap and point *X*, there still would not be a particle of foul air puffed out at the fresh-air opening, if the fresh-air pipe is of greater length than the distance between *X* and the trap.

After the fixture water reaches *X* connection when *X* is made in a larger and horizontal pipe, its interference with the air is not considerable.

The object in not connecting the loop stacks as close together as fittings will permit, is to keep the water, as it turns into the horizontal main, from interfering with the entry of air to the vent. By giving some distance to travel before reaching the loop connection, the discharge of water will be well spread in the main line before passing it. From this point on, it may cause violent eddying of the air in the main, but no actual reversal of the current will take place.

The force of air in front of water in down-spouts that connect inside of the intercepting trap, may at times reverse the air in the fresh-air inlet proper. The loop pipe is an aid in this respect, too, as more air is at hand to cushion the rush of a sudden downpour; and the various fixture trap seals are, if affected at all, left much more stable. It would, if necessary, be better to have soil-pipe air expelled from an inlet, at times, by the action of storm water, than to incur the risk of siphonage or waving-out of fixture trap seals for lack of it.

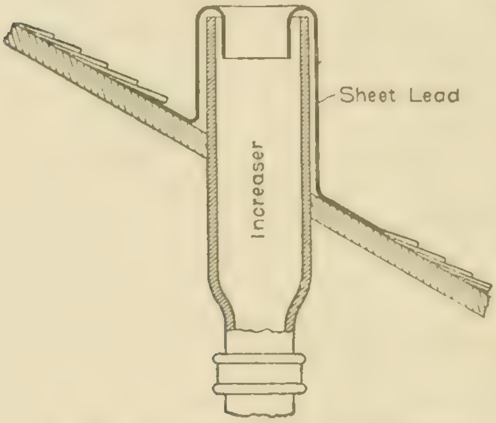


Fig. 148. Vent Pipe Increased in Size Before Passing through Roof, to Prevent Closure by Hoar Frost.

No pipe of any building should open to the air with less than a 4-inch end. Small pipes should be increased to 4 inches before passing through the roof, as shown in Fig. 148. Pipe 4-inch and larger, up to 6-inch, should be increased to 6-inch. The object in all cases being to prevent closure by hoar frost. With 6-inch and larger pipe, it is doubtful if it is ever necessary to increase the size at the roof, excepting in buildings with cold roof space, no matter how high the building may be; yet some city ordinances call for an increase of one size regardless of size, which is manifestly foolish, as it permits increasing 2-inch to $2\frac{1}{2}$ or 3-inch on any type of job, and this is known to be inadequate in any but southerly latitudes. The velocity of air up the line is, of course, higher in tall buildings than in low ones; hence, in them, more moisture is carried through any given opening, and the theory of increasing large pipe at the exit is based on the assumption that smaller openings would, as a result of this excess of moisture, be closed by frost. The great amount of warmth over large buildings must often, however, be considered as reducing the chances of closure by hoar frost. In tropical climates, no increase of any size is necessary. In southerly temperate latitudes, no special attention is given precautions against hoar frost, beyond increasing the size of small vents to at least 4 inches in diameter.

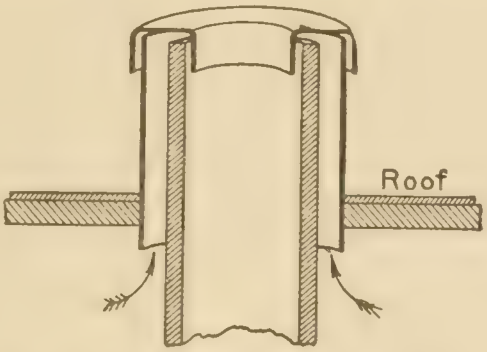


Fig. 149. Pipe Flashing Capped with V-Ring of Lead and Providing Egress for Warm Air from Attic.

Flashings. There are patent devices for flashing around pipes, usually made of copper; but the plumber will do well to command the skill necessary to manipulate sheet lead to suit conditions as he finds them. In any location where warm air will always be seeking an outlet from the attic through chance openings, the sleeve of the flashing may be made two to four inches larger than the outside diameter of the vent, and capped with an annular V-ring of lead in the manner shown in Fig. 149. The cap ring need only be tacked to the sleeve with solder. The top edge of the sleeve should be notched or some other provision for air-exit made, so as to insure constant changing of the air in the sleeve. If, on account of braces or projections necessary to hold the pipe rigid where it passes through the sheeting, it is inconvenient to let the sleeve extend below the sheeting as shown in the engraving, it may terminate at the roof line. If the building is a storage warehouse, or for any reason the attic will not be very warm, or conditions are in favor of cold air being drawn in through chance openings in winter, then the method of flashing and packing the sleeve with felt or mineral wool as shown in Fig. 150 should be employed. In all cases the vent and flashing must rise above the possible snow-level for flat roofs. The snow-level on a steep roof will be less, but drifts may obstruct the vent if left at the snow-level. Some latitude for

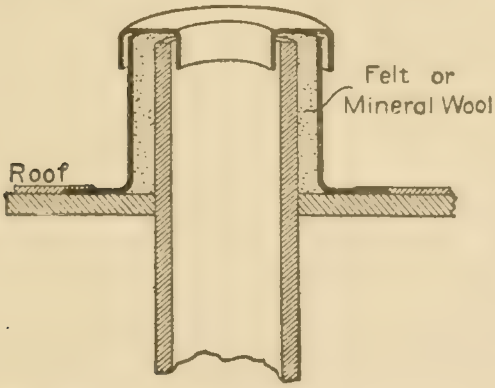


Fig. 150. Pipe Flashing Packed with Felt or Mineral Wool where it is Desirable to Conserve Warmth in Attic.

settling of the roof under the weight of snow and ice, and for expansion of lines supported by brick piers or other supports far below the roof-level, must be allowed in fitting flashings. If they are too closely drawn or capped, trouble will soon follow.

To develop the pattern for a tapering sleeve for a vent for a flat or nearly flat roof, draw, as in Fig. 151, *XY* at random; set off *AB* equal to the altitude of the sleeve; then *AC* from *A*, perpendicular to *AB*; then *BD* from *B*, parallel to *AC*; let *AC* equal half the diameter of the sleeve at the top, and *BD* half the bottom diameter; then cut *CD* with a line crossing *XY*. Lines *AC*, *CD*, *DB*, and *BA* now outline half the elevation of the sleeve at the center. Next, with the intersection of *XY* and *CD* projected (*X* in the diagram) as a center, describe the arcs *EF* and *GH*. On *EF*, set off the circumference of the base of the sleeve *JK* (twice *BD* × 3.1416), and then indicate *JX* and *KX*. This develops the net pattern, and it remains only to add the necessary working edges to get, when cut out and formed up, a sleeve exactly conforming to the shape and dimensions required.

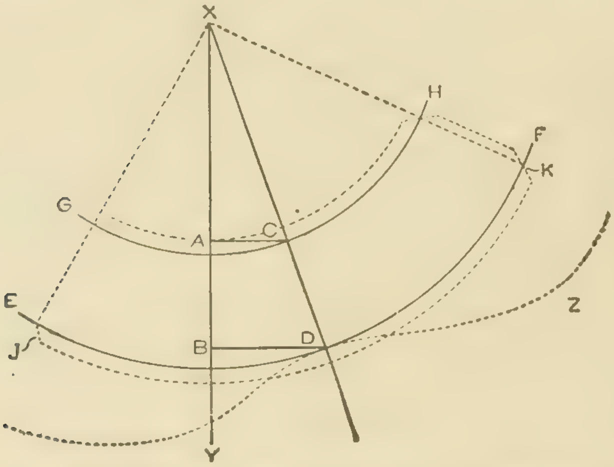


Fig. 151. Development of Pattern for Tapering Sleeve for Vent on a Flat Roof.

The development of a tapering sleeve for a pitched roof by strictly geometrical methods, is so intricate, and the springs and pitches of roofs so varied, that the plumber usually ignores—and is generally sensible in doing so—the true methods of cutting out such flashings. Lead is pliable; and in lieu of the more tedious method, flashings for pitched roofs are roughly laid off as follows, and then worked and trimmed to suit.

The circumference and curvature of the top edge and lines of the ends to be joined, are obtained by full-size diagrams in the same way as for a sleeve for a flat roof, shown by Fig. 151. The circumference of the top edge is, in this case, set off on GH, because the bottom, corresponding to *JK*, is unknown. The elevation *A B C D* is made just as though a sleeve was to be made for a flat roof, with the tapering side equaling *CD*, Fig. 152, which should be laid out to represent the elevation of the sleeve desired. The pattern diagram (Fig. 151) should be so drawn as to throw line *XCD* about the center or neck of the pattern, so as to bring the seam on the low side and thus present solid metal to the flow of water down the roof. The line of dots marked *Z* in Fig. 151, approximately outlines the bottom of the pattern. The cross-mark guides by which to draw the bottom of the flashing, are seldom more than five in practice, and their positions are determined in this way: *JX* and *KX* of the pattern diagram are extended and set off from the *GH* line equal to *XK*, Fig. 152. This gives the actual seam length for the low side of the flashing, as would be indicated if *XJ* and *XK*, Fig. 151, were extended to cut the extremes of the cross-mark guide line. *CD* of both the elevation and pattern diagram being equal, *CD*, Fig. 151, equals the length of sleeve in the neck or upper side. For the length of sleeve at the sides, half way between the neck and seam, produce dotted line K^1Y, Fig. 152, parallel to *CX*, to a point where it will intersect the roof-plane at the center of the pipe space. K^1X will then be equal to the required side lengths of sleeve, and may be set off on the pattern diagram by projecting radii from *X*, cutting the pattern midway between *C* and the seam lines, and setting off the distance XK^1 on these radii, measuring from the *GH* line. These specific points are a sufficient guide for laying out the bottom in any ordinary case.

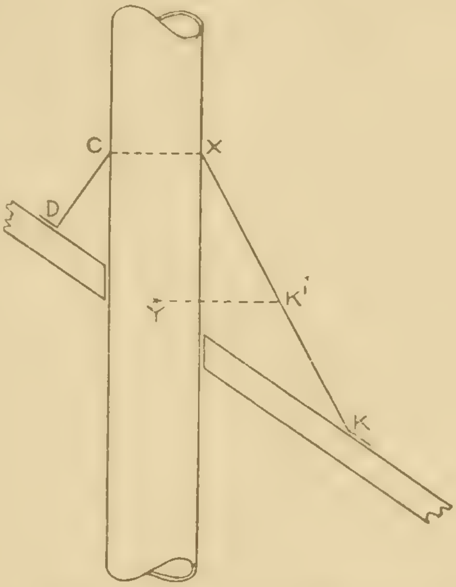


Fig. 152. Elevation of Tapering Pipe-Sleeve for Pitched Roof.

Trap Ventilation. Needless multiplication of soil and vent connections may lead, in some cases, to conditions fully as deplorable as any that would follow the primitive simplicity of olden times. There are, however, certain principles that must be carried out to secure a perfect working job. These have often been curtailed by the extremists of one class, and always at the expense of the quality of the work. It is the extremists who regulate progress and keep things at a reasonable mean. The extremists in progression would drag us into practices perhaps unsafe; while their opposites, derisively termed "old fogies," hold us back, sometimes on untenable ground. The result is that the conservative element is the safest class to follow; it neither discards a well-tried method nor embraces a new one, without good reason to sustain the action.

As before intimated, the change in character of buildings and mode of life has necessitated a maze of pipe work in some buildings, which to the uninitiated looks like a senseless network thrust on the owner to the pecuniary gain of the plumber. This is not the case, however, as every plumber well knows; and there is no better way to disarm this type of credulity than for the plumber to be well versed in the philosophy of his business.

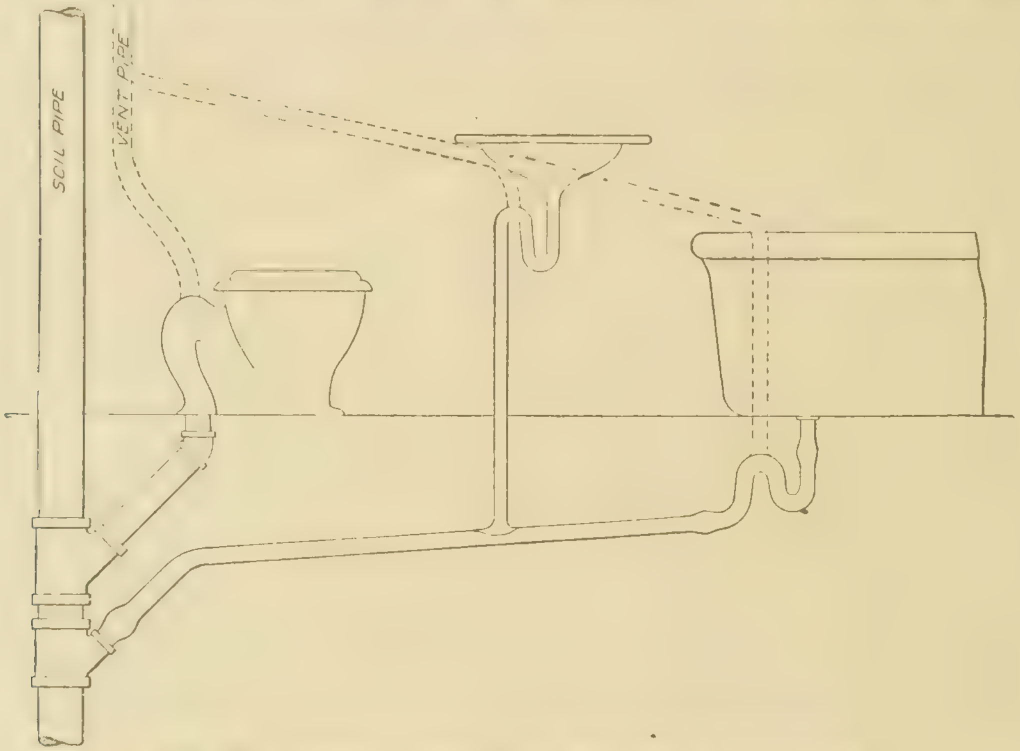
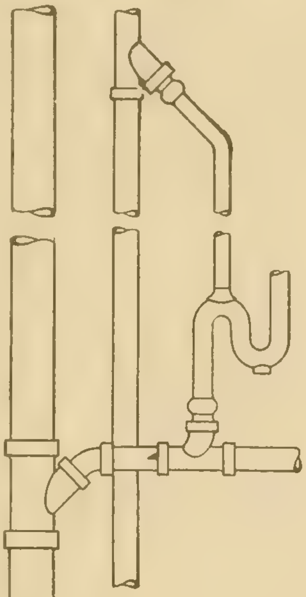


Fig. 153. Common Form of Crown and Stack Ventilation.

The familiar cry that crown ventilation of traps destroys the seal by evaporation, is often but the echo of the voice of a man with an axe to grind. The deep-seal trap costs but a trifle more than the ordinary. There are also positive mechanical means—comparatively cheap, too—of protecting a vacant or unoccupied house against sewer air. In occupied houses, there is no chance for traps to lose the seal by evaporation; and, when properly piped, the evaporation of seals does not take place so fast as might be supposed. The crown vent is merely, or should be, to keep the water from being siphoned out of the trap. It is the practice of making the crown vent do duty not only as a siphon-preventer but also in the capacity of a stack vent, that has created the impression as to rapid evaporation.

If we bring a branch waste to a fixture just as though it was to be a "dead-end" connection, and then put in a liberal crown vent continued to the roof, as shown in Fig. 153, we have filled the letter of most specifications, because we then have *crown ventilation* and *stack ventilation.* But this is not the spirit of the work specified, nor is it up to the standard of intelligent workmanship. The current to the roof passes up the trap leg, and thence through the crown vent directly to the open, being brought on its way in close proximity to the seal of the trap; and it is no cause for wonder that such a connection would



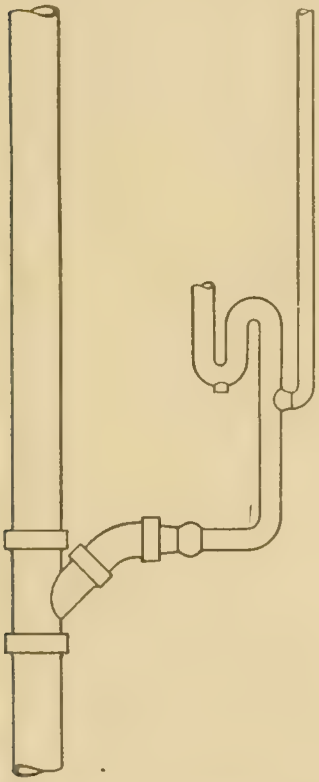


Fig. 154. Prevention of Siphoning Thwarted by Improper Placing of Vent Connection.

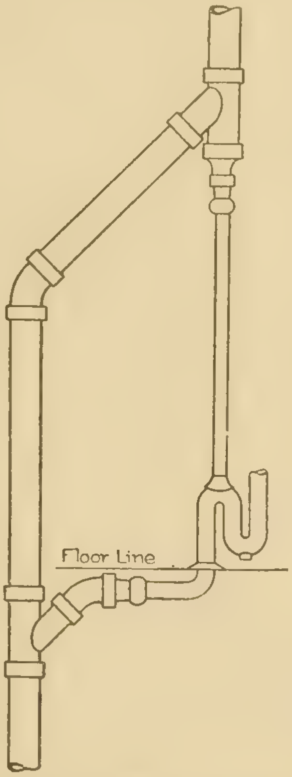


Fig. 155. Waste Stack Connected to Vent Stack above Highest Fixture.

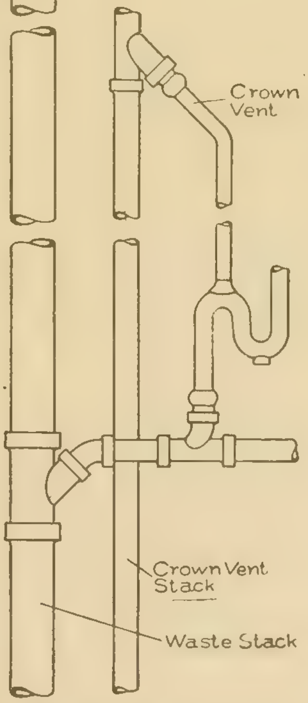


Fig. 156. Crown Vent Stack and Waste Stack Standing Close Together, Giving Loop Effect in Pipe Ventilation.

rob an ordinary trap of its seal within a surprisingly short time, if the fixture is left unused. This is the type of installation found in the wake of speculative builders, scrimping plumbing contractors, and ignorant or unscrupulous journeymen. Many examples of this double-duty vent pipe are seen, in which the workman foresaw the result to some extent, and, in attempting to counteract the supposed ills of evaporation, made the vent useless as a siphon-preventer by connecting the vent 10 inches or more below the crown of the trap, as shown in Fig 154. The proper way is to make both the waste and the crown vent branches from other lines. Of course, if it is the top fixture, or there is only one on the line, the waste stack may end in the beginning of the vent stack or connect into the vent stack, as in Fig. 155, according to circumstances. The main current goes by the most direct route —up the main waste and vent stacks of the string. If the crown vent and waste stacks stand close together, as in Fig. 156, we have the loop effect before spoken of; and with the fixtures near the stacks, the waste and crown-vent connections are both short—which is proper. It is poor practice to have the stacks far away from the fixtures, because one is then likely to fall into the error of allowing the crown vent to act also as a direct line vent for the branch waste. This plan is such a short-cut to accomplishing the work of roughing-in, that the temptation to err is great. If the waste stack cannot come near the fixture, then follow the loop principle, and turn up and into the vent stack, branching the trap into the waste branch, and taking the crown vent into the vent stack, as shown in Fig. 157, or into a vent continuation of the branch waste, as preferred. If neither main stack can come near the fixtures, then loop out from the soil or waste stack to the fixture, and back into the main vent, leaving enough upright

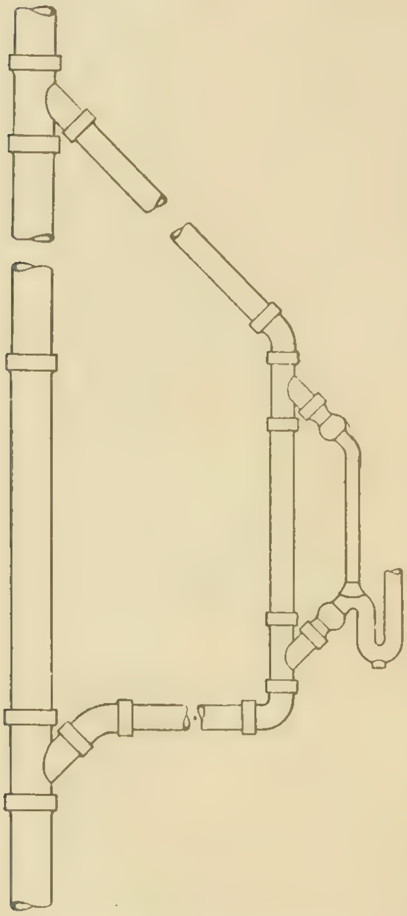


Fig. 157. Method of Securing Loop when Waste Stack is not Near Vent Stack.

pipe at the fixture end of each loop to branch the waste and crown vent into, as illustrated in Fig. 158. In this way, half of the branch loop acts as a waste, and half as a vent, and there is ventilation through the soil or waste branch part without continually pulling the air into juxtaposition with the trap seal. Also, the local branch waste to the trap and the crown vent pipe are thus permitted to be as short as desired.

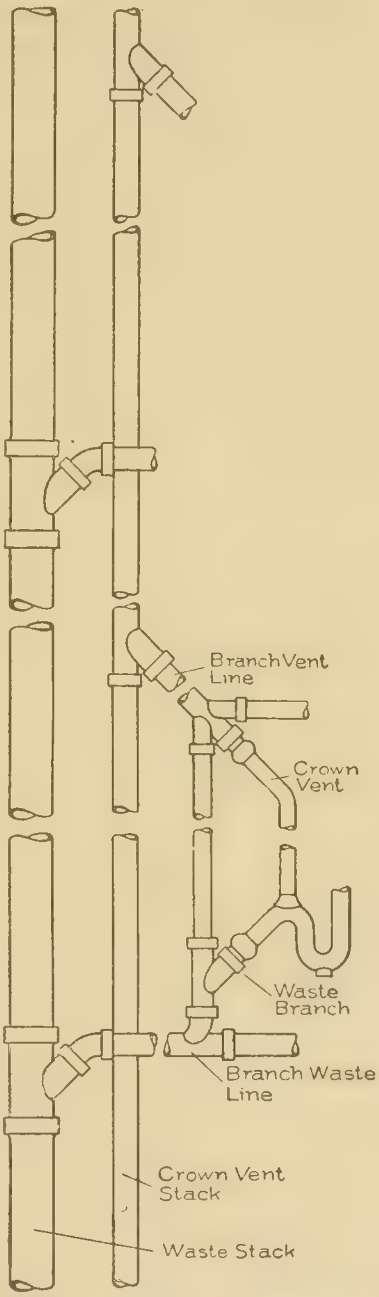


Fig. 158. Method of Ventilating Pipes where Neither Waste Stack nor Crown Vent Stack are Near the Fixture.

To avoid separate stacks for scattered fixtures, what is termed the *continuous system* of soil pipe is frequently employed when practicable. This means offsetting the main so as to be able to include all the fixtures of a toilet-room without making long branch wastes. If vent lines are also offset in this manner, some provision for water-washing the offset should be made, as the products of corrosion or other foreign matter might otherwise fall into and choke the bend at the foot of the upper vertical part. Especially is this true when plain wrought pipe is used. Lavatory wastes are generally used to wash vent lines in such cases.

Some city ordinances permit the continuous system practically without vents, merely requiring the fixture connections to be not over 3 feet in length, and requiring either vents or non-siphoning traps where the stack cannot be brought within reach of the 3-foot limit placed on branch connections.

A plan of offsetting, some modification of which may be used in any kind of system, is shown in Fig. 159, which makes plain the work of offsetting soil waste and vent lines without incurring the risk of having trouble with the vent pipe sooner or later. It provides for throwing the corrosion of the vent line, both above and below the offset, into the soil line, where it will be washed into the sewer by the water discharged from the closets and other fixtures. By simply offsetting the vent line, the corrosion from the pipe above the offset will fall into the bend, drift out into the horizontal part slightly, and finally choke up the horizontal vent altogether. As shown by the engraving, commencing with the main soil line at the first fixture, a branch line is made, and the *branch* then becomes the main soil line, leaving the vertical part for the vent. Next comes the offset, and after that another branch line for soil fixtures, again leaving the vertical pipe for the vent, so that whatever falls down the vent, either above or below the offset, lands in the soil pipe and is carried away with the water. With this arrangement, the only possible chance for the vent to clog with corrosion is in the horizontal part of the vent offset. What corrosion takes place in a piece of horizontal pipe, is not sufficient to warrant consideration in itself. There is no other corrosion to be taken care of, except that which forms in the few feet of vertical pipe between *A* and *B*, which will not be enough to restrict materially the area of the pipe. It is best to make the piece of pipe between *A* and *B* as short as possible.

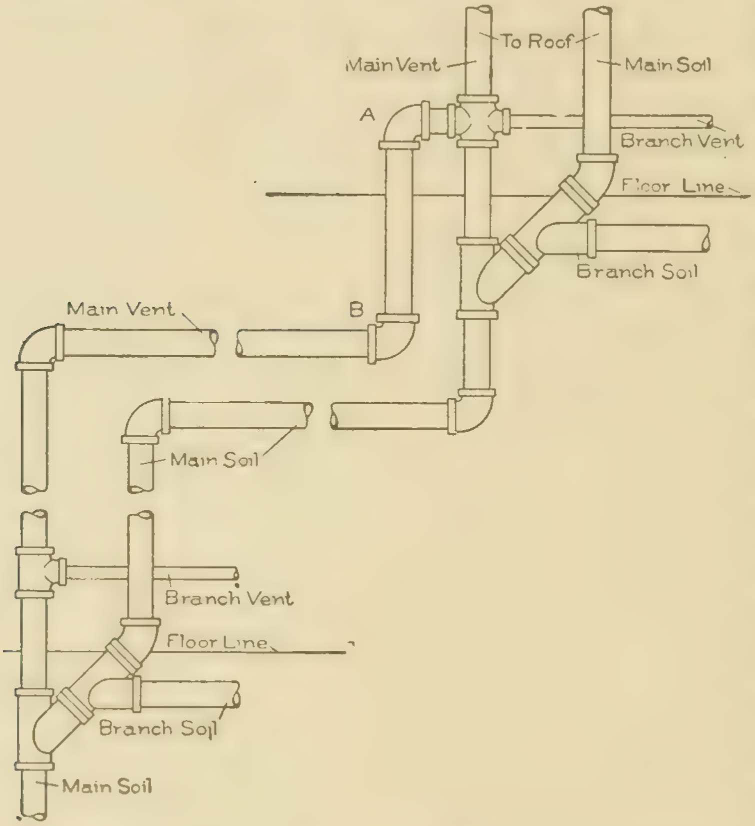


Fig. 159. Method of Offsetting Soil Waste and Vent Lines.

With the continuous system, several offsets, simple or more or less complex, as shown in Fig. 159, may be necessary in the same stack, according to location of fixtures and the scheme of venting and trapping. Fig. 153 shows a group of fixtures piped diametrically opposite to the continuous stack idea. The main stack does not deviate in favor of odd fixtures. Regular open wall-traps are used. The crown vents are assembled into one stack, and carried up independently or into the stack above the highest fixture. As before stated, the plan shown in Fig. 153 is faulty in that it favors evaporation of the trap seals by putting the extra duty of a line-vent current on the siphon or crown-vent branch.

Anti-siphon traps often simplify ventilation problems, especially in awkward situations where it would be very difficult to vent a fixture properly with pipe. Fig. 160 illustrates an example of this kind, in which non-siphoning traps are used on bath and lavatory without any form of crown or branch line vents. In good practice, bath traps are placed convenient to reach, having screw-top hand-hole with cover in full view at the floor-level.

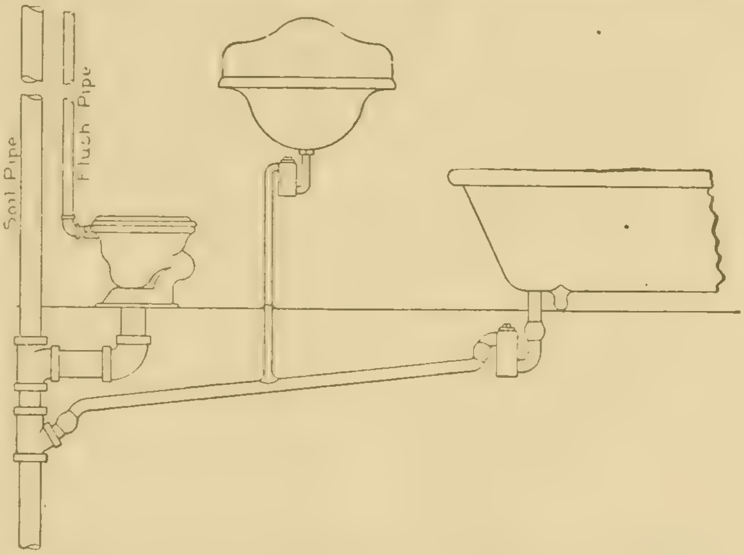


Fig. 160. Anti-Siphoning Traps Dispensing with Necessity for Vent Lines.

Soil Stacks. The size to make a soil stack is largely a matter of opinion. There are examples of 10-inch stacks serving 40 closets with the usual complement of lavatories and urinals. There are also instances where as many as 75 closets and numerous other fixtures all discharge into a 5-inch stack which has never given any indication of being too small. Although common usage requires a 4-inch soil stack, there seems little advantage in adhering to this dimension in small and simple installations. When the plumbing was designed for the city of Pullman, Ill., more than twenty years ago, 3-inch soil stacks were used for small dwellings, and in some cases they were placed in a party wall, so as to afford service for two adjoining houses. The plumbing regulations of Washington, D. C., have allowed for some years past the construction of 3-inch soil stacks for dwellings having only a single bathroom, and the practice has been justified by favorable results. When it is considered that the outlet of a closet is rarely more than $2\frac{1}{2}$ inches in diameter, it appears that a size smaller than 4 inches is often allowable.

The size does not increase with the number of fixtures. Very few of a hundred closets in a building would ordinarily be flushed simultaneously. A 5-inch stack would answer well for 100 closets in a tall building where the toilet-rooms are superimposed, as shown in Fig. 161, which outlines the soil, waste, and vent pipes of several groups of fixtures, rain-water leaders, etc. If the same number of closets were at one elevation, and the fall only moderate, common sense would dictate a 6, 8, or 10-inch line, with 4-inch fixture branches.

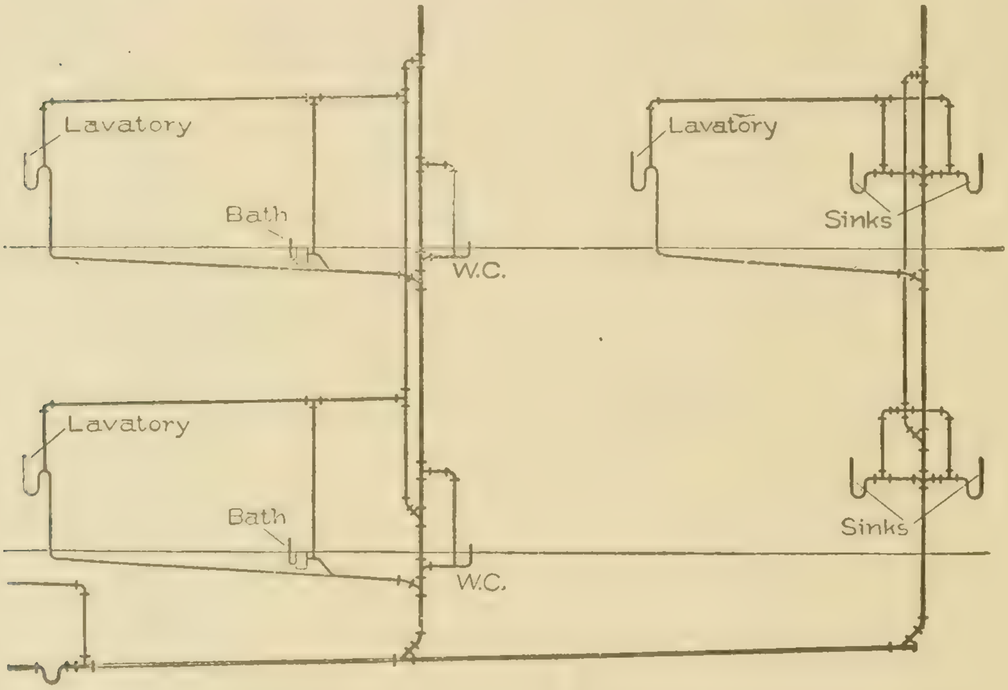


Fig. 161. Showing Layout of Soil, Waste, and Vent Pipes of Several Groups of Superimposed Fixtures in Same Building.

The velocity with which the water will flow away should be a prime factor, but sizes in soil and waste pipes are far more a matter of empiricism than in supply work. A soil pipe not too large is self-scouring in a sense. This point is erroneously argued in favor of small waste pipes. If a soil pipe too small for the duty should be installed, ordinary usage would develop the fact quickly. But in a waste outlet, where grease is likely to accompany the water, a pipe large enough to carry the waste easily when the pipe is new, may become choked after a considerable period of time, and merely because it is of the size so-called "self-scouring." A house line which may be much too large for the waste will be likely to choke from floating matter adhering to the sides above the water line until overhanging ridges are formed that break down in the channel. Being too heavy for the water to push along, this matter acts as a dam, and complete stoppage soon results. This is why large sewers are built with elliptical bottom section. Having variable flows to take care of, the depth of water produced by ordinary usage cleanses the conduit, and keeps it in much better condition than if round conduits of the same capacity were employed.

Slope. With due respect for appearance, all the fall possible should be given lateral soil and waste lines. About $\frac{3}{16}$ inch to the foot (one degree) is taken as the minimum. With cast pipe and leaded joints, much more than this can be given, by gaining change of direction in setting the joints. With screwed fittings for wrought pipe, tapped, pitched one degree from the nominal angle, less latitude to vary the fall is offered. Considerable variation is possible, however, by cutting pitched threads on the pipe. In positions where the cutting of one pitched thread entails the work of cutting another with the pitch just opposite that of the first in order to follow the perpendicular again, the work is irksome and is seldom resorted to. Cast fittings, threaded, for drainage work, are recessed in the ends, so that, when screwed on the pipe, the pipe and interior of the fitting are of the same diameter, thus presenting no jog or broken edges to favor stoppage. Stoppage of drains of any kind is likely from many causes; and during installation, trap-screw ferrules, or tees with brass plugs, according to the kind of pipe being used, should be provided along the line, as

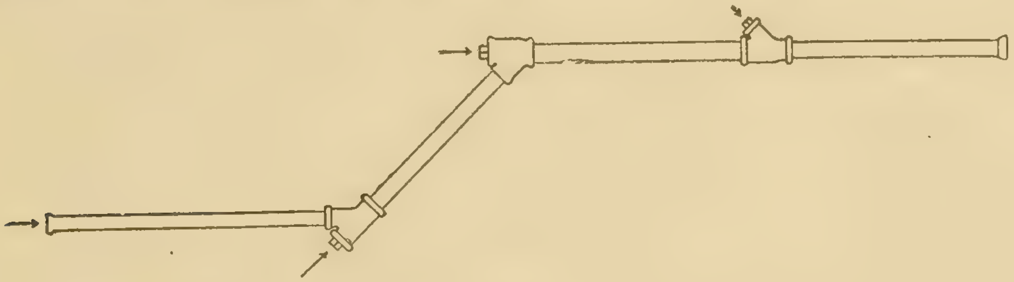


Fig. 162. Trap-Screw Ferrules Installed at Intervals to Facilitate Cleaning of Drain Pipe.

shown in Fig. 162, so as to make the work of cleansing as convenient and inexpensive as possible.

Sizes of Soil and Waste Pipe. The usual sizes for soil and waste work are: 5-inch for ordinary house main (horizontal); 4-inch for 1 to 4 closets; 5-inch horizontal-branch from 5-inch stack for a battery of five or more closets; 5-inch stack for any ordinary number of fixtures; main vent stack, same size as soil-stack; loop vent, same size as stack; crown-vent stacks, 2 or 3-inch; slop-sink stacks, 3 or 4-inch; closet connection, 4-inch; closet crown vent, 2-inch; slop-sink connection, 3-inch; slop-sink vent, 2-inch; urinal stacks, 3-inch; urinal branch wastes, 2-inch; urinal trap vents, $1\frac{1}{2}$ to 2-inch; bath stacks, 3-inch; bath-waste connection, 2-inch; lavatory wastes, 2-inch. The 2-inch refers to the size of cast pipe used in the case of lavatories and baths; the lead trap and connections of these, and often of other fixtures, are made $1\frac{1}{2}$-inch. Small lavatories often have $1\frac{1}{4}$-inch waste. The crown vent is usually one size less than the trap for all but closets and slop sinks. Of late, bath-waste outlets are frequently made 2-inch. Kitchen-sink stacks are made 3-inch; single sinks or branch waste for one sink or set of trays, 2-inch, with 2-inch trap and $1\frac{1}{2}$-inch crown vent.

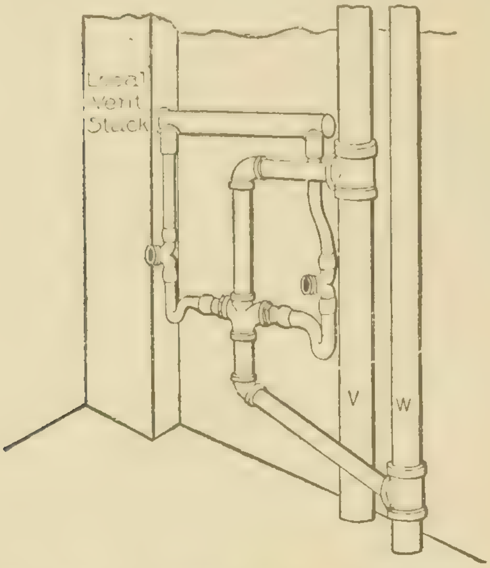


Fig 163. Local Ventilation for Two Urinals.

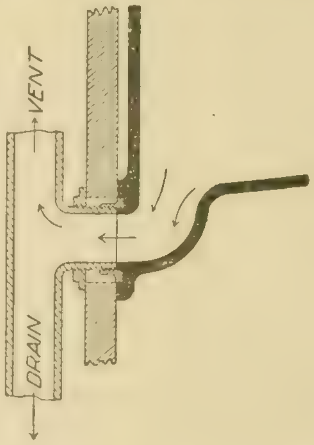


Fig. 164. Part Section of Locally Vented Urinal and Connection.

Local Ventilation. A local vent is a pipe leading air from the bowl of a closet or through the outlet of a urinal to carry away odors with a current of air fed by the air of the room. In Fig. 163 are shown two openings for urinals where the roughing-in provides for local ventilation for the urinal bowls in a way that is equivalent to the local vent pipe to a closet bowl. *V* is a general vent stack, and W the urinal waste stack. Instead of putting in crown vents for the traps, the branch waste becomes a vent at the junction of the trap branches, and loops back into the general vent stack. There is sufficient ventilation in this case for two reasons—the traps are close to the line; and the current up the main local vent stack is induced and maintained by a fan motor, which, in drawing the odors from the urinal bowl, creates more or less suction on the house side of the trap seals and counteracts the tendency toward siphonage on the sewer side. The roughing-in shown, is hid by marble slabs in the finished work.

A section of the marble back, with urinal and vent and waste connection, is shown in Fig. 164, which makes clear what is meant by local urinal ventilation. The difference between it and local closet ventilation, is that as the trap for the urinal is not in the urinal proper, the current from the room passes through the urinal outlet except while it is flushing; while in the closet the local vent connection is made to the bowl above the visible water-level, because the trap below interferes with connecting it otherwise.

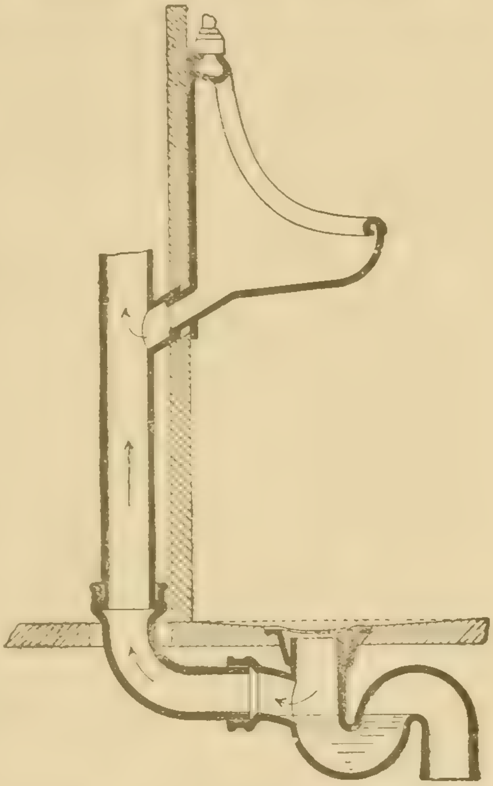


Fig. 165. Locally Vented Trap for Urinal and Floor Drain Combined.

Another plan of local-venting a urinal is shown in Fig. 165, in which the urinal trap answers as a trap to the floor drain as well, and the local-vent current passes down through the grating of the floor-slab drain and up through the urinal waste to the point where the urinal proper connects. Between the trap and urinal connection, the pipe is a waste and local vent combined, its continuation above the urinal vent connection being simply a local vent pipe, the area of which being equal to the combined area of the urinal outlet and floor-slab grating, a current also passes from the urinal bowl through its outlet into the local vent pipe. The only fault to be found with this arrangement is the abnormal distance of the trap from the fixture, which, however, is of little consequence so long as the means for pro-

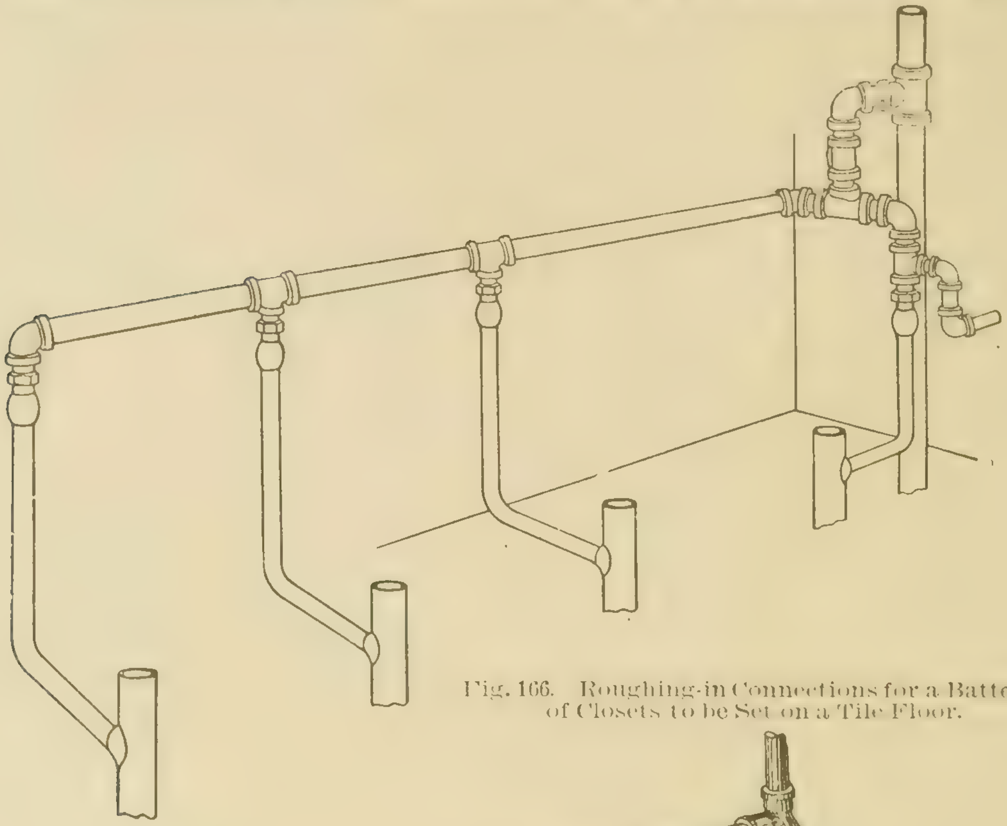


Fig. 166. Roughing-in Connections for a Battery of Closets to be Set on a Tile Floor.

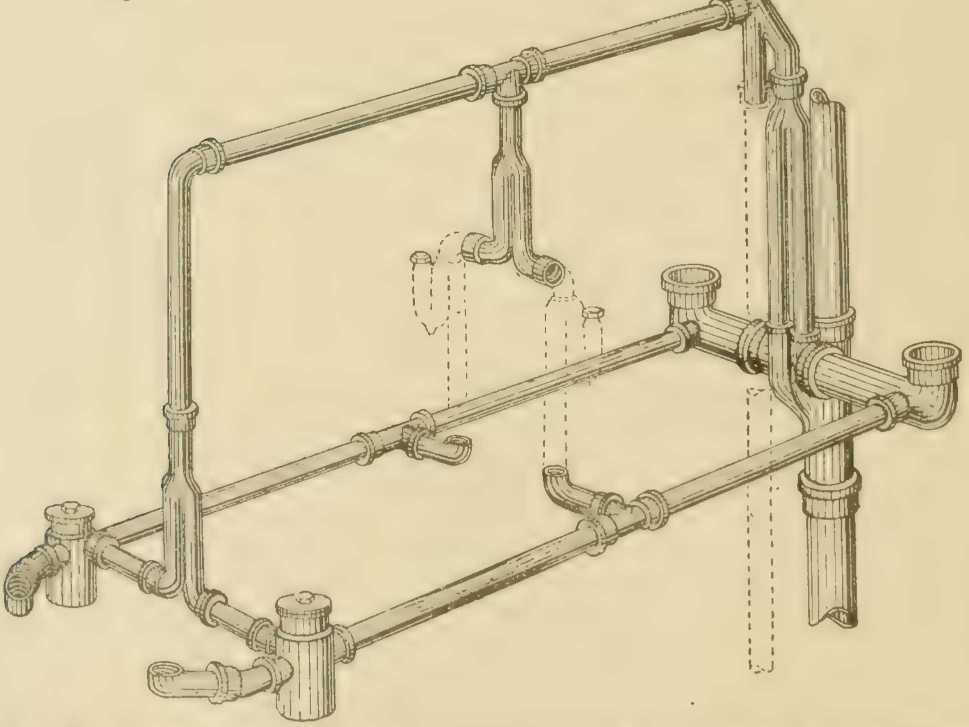


Fig. 167. Roughing-in for Adjacent Toilet-Rooms on Same Floor of Double-Flat Building.

ducing a current in the local vent stack is doing its duty. Fig. 166 shows the openings left for a battery of closets that are to be set on a tile floor. The uprights connect into a branch soil line below. The illustration is given to show a system of venting which can be used with closets that do not permit of crown venting.

Local vent stacks are round or rectangular, and are made of galvanized sheet iron. Unlike the soil or supply pipe system, the stack system is made proportional; that is, the area of the stack at any point is an approximation to the aggregate area of all the vent branches that have been connected into it up to that point. The local vent stack is sometimes carried into the same shaft which incloses the smoke-pipe from the boilers. In other cases it is connected

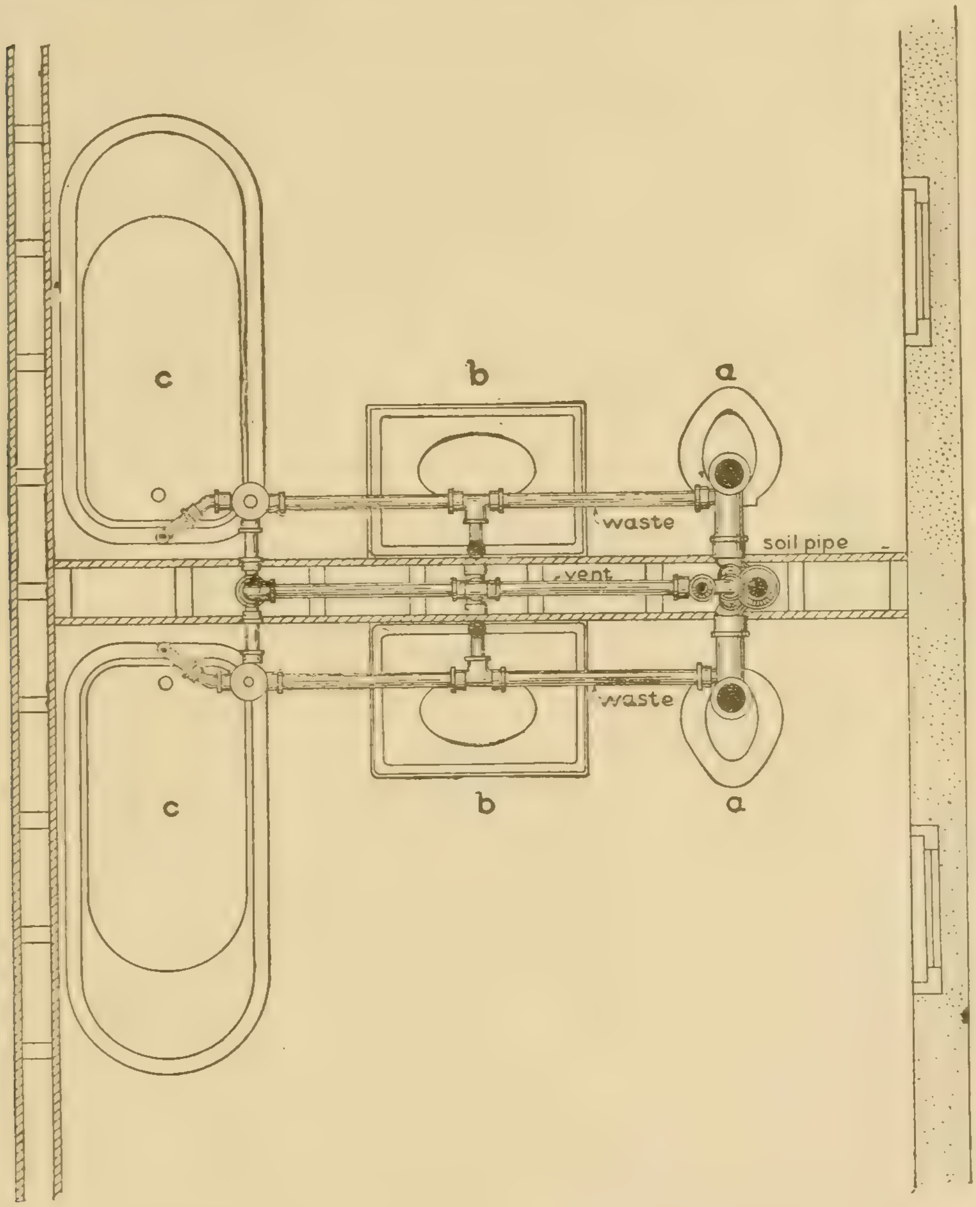


Fig. 168. Plan of Complete Installation Shown in Part in Fig. 167.

with an exhaust fan driven by power, usually supplied by an electric motor, thus insuring a constant air-current. Bowl or local ventilation is not generally installed in dwellings. The closet does not receive such frequent usage in private houses as in larger buildings such as hotels, offices, etc.; and in the smaller structures there is no hot flue that can be depended upon for purposes of aspiration. If led to the open air, the vent will act very well in warm weather; but during the winter months it will be likely, through reversal of the current, to bring in cold air and disseminate the odor through the apartment.

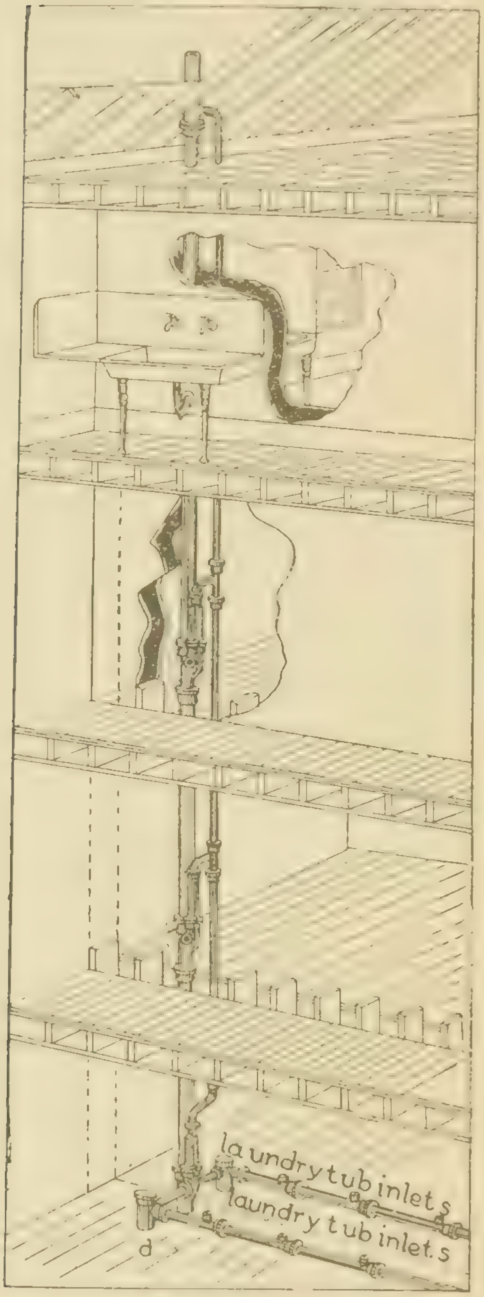


Fig. 169. Broken General View of Waste and Vent Stacks for Laundries and Kitchen Sinks of a Flat Building.

Soil Pipe and Fittings. Under the head of *specialties*, many forms of patented soil-pipe traps and fittings have been placed on the market from time to time, with a view to lessening labor and cost and simplifying the work of roughing-in for plumbing fixtures. Of these, a singular instance of the use of one type will be noticed. Fig. 167 illustrates a well-known line used in roughing-in for the toilet-rooms of a double-flat building. Being drawn in perspective, the function and merit of every fitting shown is self-evident. Fig. 168 gives in plan view the roughing-in shown in Fig. 167. The location of the fixtures on the floor below the plan of piping, is indicated in solid lines by *a*, *b*, and *c*. On other floors, corresponding fixtures for the stack shown, are of course superimposed as a matter of economy and convenience. Fig. 169 is a broken general view of the waste and vent stacks for the laundries and kitchen sinks of the same building, the roughing-in work and some of the fixtures being shown. The regular standard soil-pipe and fittings can be made to answer for any case, although inconvenience and additional expense are often incurred in working fittings of standard dimensions in close quarters.

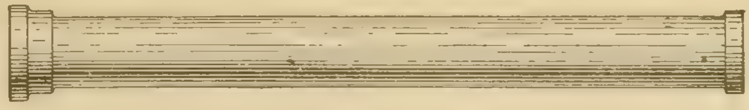


Fig. 170. Single-Hub Length of Standard Soil-Pipe.

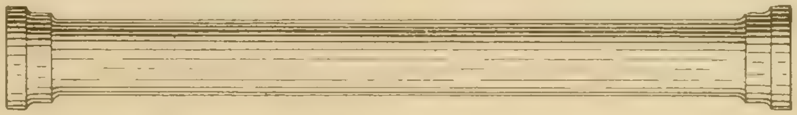


Fig. 171. Double-Hub Length of Standard Soil-Pipe.

There are several weights of soil pipe and fittings used, varying with the building or with the requirements of city or state sanitary laws, etc. The weight known as *standard* is sometimes used on buildings under four stories in height, and for vent pipes and soil-pipe extensions above the highest fixture. Extra heavy pipe and fittings are used in tall buildings and in most ordinary work, for all soil and waste purposes below the highest fixture. The standard length of soil pipe for all diameters, is five feet, exclusive of hub.

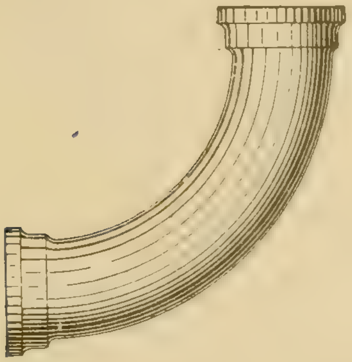


Fig. 172. Quarter-Bend with Double Hub.

Fig. 170 shows a regular single-hub length. Fig. 171 represents the double-hub length employed to avoid the use of double-hub fittings and extra joints where less than full lengths are required in cases where the cost of regular extension pieces would exceed the price of double-hub pipe. Fig. 172 is a quarter-bend with double hub. It is of the long-sweep or long-radius pattern. The whole list of standard regular fittings is made in the long-radius pattern. They

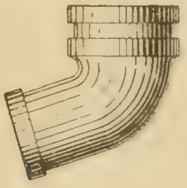


Fig. 173.

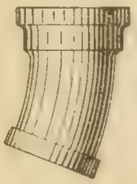


Fig. 174.

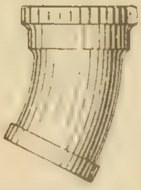


Fig. 175.

Short-Radius Bends for Soil-Pipe.

should be used where possible; but the shorter-radius type, corresponding to that shown in Figs. 173 to 180, is most generally employed because the little room available enables the plumber to lay lines in places where cramped conditions make the use of the long radius impossible.

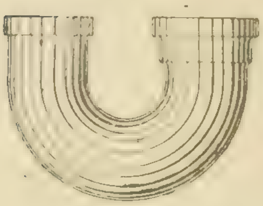


Fig. 176. Return Bend for Cast Soil-Pipe.

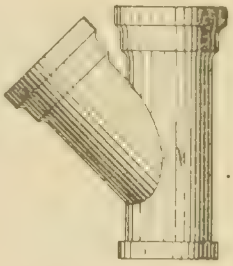


Fig. 177. Single Y.

One-sixteenth, one-eighth, one-sixth, one-fourth, and return bends embrace the regular list of soil-pipe bends, giving a range in angles from 22½ to 180 degrees in the same plane; and, by winding them, giving a twist to the joints, almost any angle with the original direction can be obtained.

A wider range of bends is offered in the recessed and threaded cast-iron drainage fittings for use with wrought pipe. Omitting the *pitched* ells and tees for regular fall, 5⅝ degrees is the most obtuse fitting regularly made.

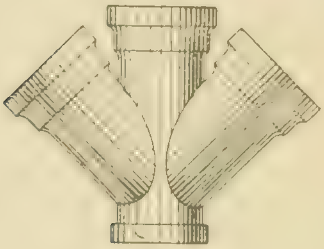


Fig. 178. Double Y-Branch.

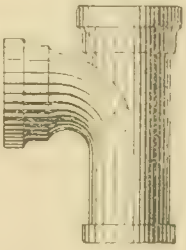


Fig. 179. Sanitary Tee.

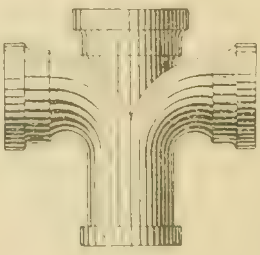


Fig. 180. Double Sanitary Tee.

The return bend for cast soil-pipe is represented by Fig. 176; single Y, by Fig. 177; double Y-branch, by Fig. 178; sanitary tee, by Fig. 179; and the double sanitary tee, by Fig. 180. The tee and double tee shown are known as the *sanitary* pattern, on account of the

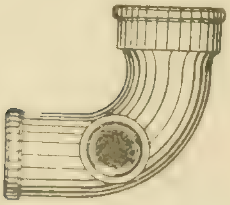


Fig. 181. Quarter-Bend with Side "Outlet."

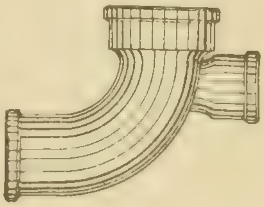


Fig. 182. Quarter-Bend with Heel "Outlet."

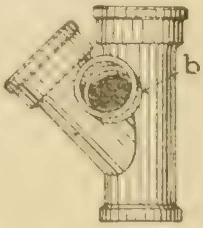


Fig. 183. Single Y with Side "Outlet."

curved branches, which direct the flow in the pipe line somewhat in the same manner as does a Y-connection. Common tees and crosses are made in strictly right-angle branches. The ¼-bend is also made with right and left side-outlet, as indicated by Fig. 181; and with heel-outlet, as shown in Fig. 182. Tees, crosses, and Y's can be had with side outlet as shown at *b*, Fig. 183. These auxiliary openings, while always termed *outlets* by the trade, are in fact *inlet* branches. Long branch fittings, with a branch equivalent to a Y and ⅛-bend connection, are also made.

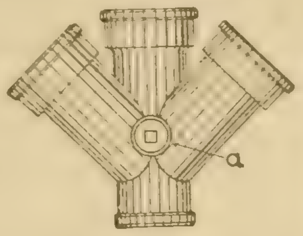


Fig. 184. Double Y-Branch with Trap-Screw Clean-Out.

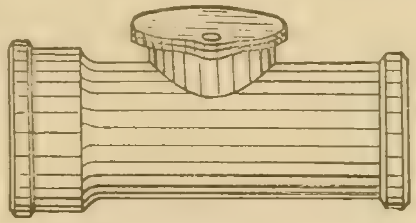


Fig. 185. Bolted-Plate Clean-Out on Soil-Pipe,

Offsets may be had to offset the pipe as little as half of one diameter, and up to six diameters. Any of the standard branches can be had with trap-screw clean-out, as shown at *a*, Fig. 184. The bolted-plate clean-out, indicated in Fig. 185, is undesirable, as the cover can rarely be securely replaced when removed for purposes of cleaning. A series of cast soil-pipe fittings are made with branches threaded for wrought pipe, as shown in Fig. 186. These meet the demand for a means of easily connecting wrought vent-pipes to a cast-iron pipe line. Similarly, combination lead and brass soldering nipples threaded for wrought pipe are now carried by supply houses, the lead being furnished straight, as shown in Fig. 187, or in the form of a quarter-bend. These are very convenient for use with wrought vents, and are equivalent to the regular combination lead and iron

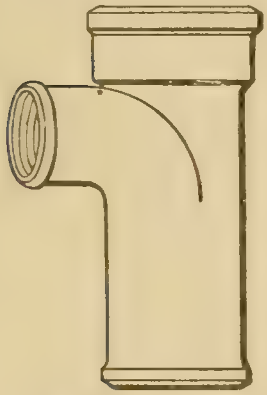


Fig. 186. Cast Soil-Pipe with Threaded Branch to Connect to Wrought Pipe.

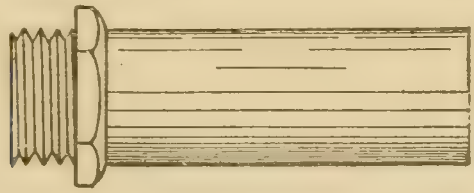


Fig. 187. Combination Lead and Brass Soldering Nipple Threaded for Wrought Pipe.

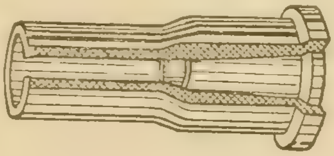


Fig. 188. Combination Lead and Iron Ferrule, "Raymond" Type.

ferrule, shown in Fig. 188; they can be used with cast pipe by calking-in. This combination ferrule—commonly known as a "Raymond" ferrule, from its maker—is sometimes damaged during the process of calking; and sometimes the outer covering is burned through in making the solder joint. For these reasons, its use is prohibited in many localities.

Brass ferrules for calking-in make a better job than lead and iron; but in case of their use, it is necessary to wipe on a piece of lead, which in cramped connections is sometimes most inconvenient; and both the ferrule and the work are more expensive.

The recessed or hub ferrule shown at *b*, Fig. 189, is a good form of ferrule. It is not satisfactory, however, as usually sold. The stock length brings the increase in diameter necessary for the recess close to the face of the hub of the fitting, making it very difficult to yarn and calk, even before the lead pipe is wiped on; and as these joints are usually wiped before the ferrule is calked in place, it is difficult to make safe joints where they are used. The forms of brass ferrule generally used are shown at *c* and *e*, Fig. 189, the lead end of *e* being contracted for use with 1½-inch pipe or less.

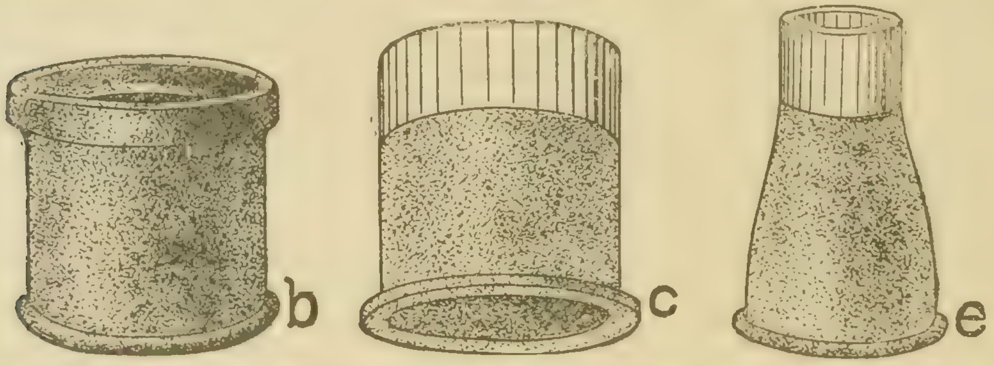


Fig. 189. Brass Ferrules—*b*. Recessed or Hub: *c*. Straight: *e*, with Lead End Contracted to Make Joint with Smaller Pipe.

Soil-Pipe Joints. A section of a soil-pipe joint is shown in Fig. 190. The materials used in making these joints are good, clean hemp or oakum, with melted lead poured in and afterward calked. The packing to support the lead should be of uniform strand, evenly twisted. When a joint is made with pipe cut to length, the bead having been cut off the spigot end, care must be taken to pack the yarn uniformly tight without driving it through into the bore of the pipe, and in a way to keep the spigot end in the center of the hub space so as to get a uniform thickness of lead on all sides. As an extra precaution in difficult places, the packing is sometimes dipped in linseed oil, and then wrung as dry as possible, before yarning a joint. This gives almost positive assurance that the joint will not leak water. Likewise, shavings of sperm candle whittled in on top of the yarn before pouring the lead, prevent water leakage.

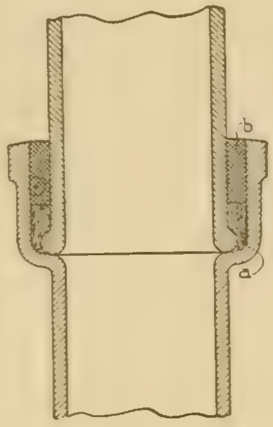


Fig. 190. Section of Soil-Pipe Calked Joint.

Some plumbers pour in just enough lead to make a ring around, and calk it down reasonably tight on top of the yarn, before pouring the hub full. Unless very little yarn is used, this does not leave a solid ring of lead deep enough to insure the best joint; and if too little yarn is employed, there is danger of the lead burning its way through into the pipe. This method is therefore undesirable in either case.

Care should be taken before pouring a joint, to see that no threads of yarn are standing above the face of the hub; otherwise a leak may result from stray threads protruding. Becoming charred by the heat of the lead, they soon leave a tiny hole through the lead, from which trouble results. No matter what the position of the joint, the entire charge of lead to complete it should be poured at one time, and the lead should be hot enough to insure a true union of the meeting edges. If the pipe is large or the weather very cold, it is better to warm the hub in order to insure the flowing edges uniting, than to risk pouring the lead so hot that it may burn through the packing.

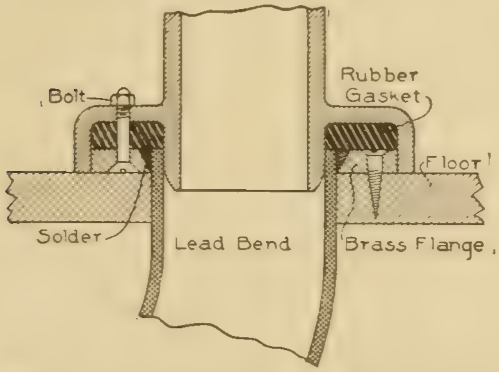


Fig. 191. Good Type of Closet Floor-Joint.

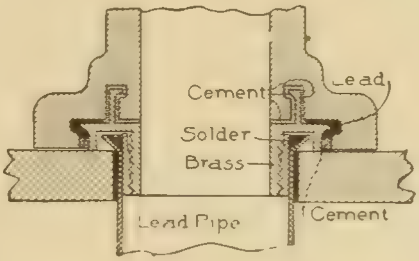


Fig. 192. Secure Type of Floor-Joint, for Closets which can be Revolved about the Outlet.

It is a matter of opinion, whether or not a joint should always be calked while it is hot. If the pipe is heavy enough to stand it without cracking the hub, it can make little difference whether the joint is calked hot or cold. If the pipe is light, a hard calking while the joint is hot and the hub expanded may cause splitting of the hub when it contracts from cooling. The best plan appears to be that of driving down the lead reasonably tight while it is hot and therefore softer than when cold, at which time it will give and adjust itself to the irregularities of the hub and spigot. Then, a little later, calk twice around with a thin-edge tool, driving the lead into contact with the spigot surface on one edge, and against the inner hub surface on the other.

Floor Joints. A closet floor joint of good type is shown in Fig. 191. In this joint, a bevel-edged brass floor-plate is screwed to the floor and well soldered to the end of the lead bend, as indicated. The floor-plate has slots for the closet bolts, so that any variation in the position of the bolt holes in the flange of the closet pedestal will not cause trouble when aligning the bolts, as they can be slid along in the slots of the plate to the required position. Common putty, plaster of Paris, or hydraulic cement may be used instead of a rubber gasket; but the latter two materials make it difficult to remove the closet from its setting, and there is always risk of breaking the flange if the pedestal has to be moved for any reason.

A secure type of joint, introduced a few years since, is shown in Fig. 192. This connection is well suited for such types of closets as can be revolved about the outlet, but cannot be used with closets where the outlet is well toward the rear of the fixture

TRAPS

Traps are made in many forms, none of which combines every desirable feature. A trap with vertical drop at the inlet is considered best for the main intercepting trap, as it allows the incoming water to break up the scum and floating matter so that it will be carried out promptly by the flow. This form also presents a difficult place for sewer rats to climb, and is therefore favored for that reason also.

In regular fixture traps, open-neck bends, and the least surface possible, are favored. The Y and $\frac{1}{8}$-bend connections in one fitting, and other fittings combining the virtues of the open bends of long-radius fittings, are used merely because they offer little chance of stoppage; but traps should have every part exposed to view in order to betray leakage. Tide-water traps are usually nothing more than simple, large, swinging check-valves. Some intercepting traps are provided with a swinging check. The tide-water feature is necessary only when high water or tides are likely to raise the water into which the sewer discharges so as to flood the cellar through fixture openings.

Siphonage. Traps introduce into plumbing the element of *siphonage.* This may be normal and desirable, as in the case of closets which discharge their contents by siphonic action; but siphonage in fixture traps, and the means of preventing it, are prime factors in every plumber's work.

Ordinary siphonage can best be illustrated by a few simple diagrams showing the principles involved. In Fig. 193 is shown a U-tube with legs of equal length, filled with water. If we invert the tube, as shown in Fig. 194, the water will not run out, because the legs are of equal length, and contain equal weights of water, which will pull downward from the top with the same force, tending to form a vacuum at *A*. Cohesion of the particles of water, together with equal atmospheric support of the water at the open ends of the tube, prevents any appreciable void space when the U is of short length. If one of the legs is lengthened, as in Fig. 195, so that the column of water is heavier on one side than on the other, the water will run out. The atmospheric pressure being practically equal on both legs, the greater weight of the water in the long end, through cohesion, assisted by the air-pressure, pulls the water in the shorter tube up over the bend, much as an unbalanced chain would run over a pulley. The columns

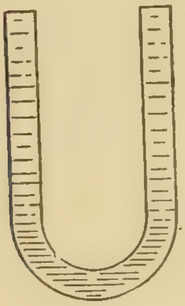


Fig. 193. U Tube with Legs of Equal Length.

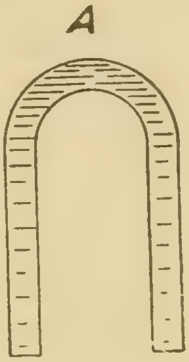


Fig. 194. U-Tube Inverted.

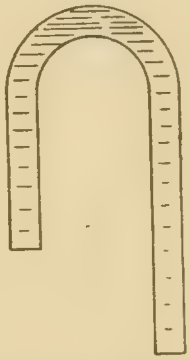


Fig. 195. Inverted U-Tube with Legs of Unequal Length.

of water in the tube in this case may be likened to a piece of rope hanging over a pulley; when equal lengths hang on each side, it will remain stationary; but if one end is longer and therefore heavier than the other, the whole rope will be drawn over by the longer and heavier portion.

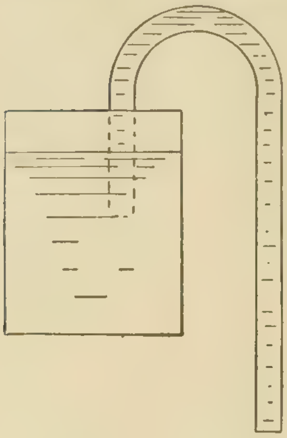


Fig. 196. A Common Siphon.

If the short leg of Fig. 195 be dipped in a vessel of water, as shown in Fig. 196, we then have the conditions necessary to form a common siphon. The atmospheric pressure, which before acted on the water at the bottom of the short leg of the tube, then becomes operative on the surface of the water in the vessel, and the flow through the tube will continue until the water-level in the vessel falls slightly below the end of the tube, admitting air and breaking the siphonic action. Gravity acts proportionally on the water of both legs of the U during siphonage, and the point of tension is therefore at the highest point of the bend.

If the bend should be pierced at the top, air-pressure would be established at both ends of each leg, and gravity would instantly empty the short leg into the vessel. It is in this manner that a crown vent to a common fixture trap breaks the flow and throws enough water back into the body of the trap to preserve the water-seal. Fig. 197 shows the principle of Fig. 196 applied to the trap of a plumbing fixture. If the bowl is well filled with water, so that when the stopper

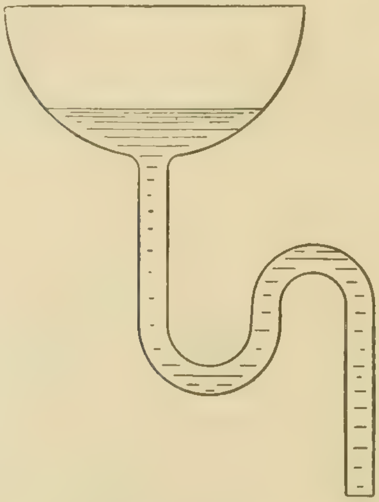


Fig. 197. Trap Fulfilling Siphonage Conditions.

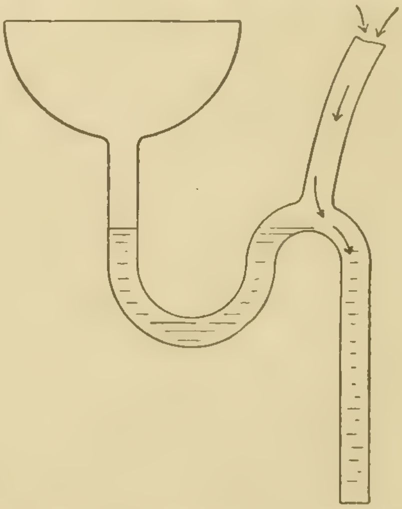


Fig. 198. Siphoning of Trap Broken by Crown Vent.

is removed from the bottom, the waste pipe for some distance below the trap will be filled with a solid column of water, siphonic action like that just described will take place and the trap will be drained. A sufficient amount of water runs down from the fixture and sides of the pipe above the trap to partially provide for the seal, its full restoration being assured when a crown vent is used, by water being thrown back from the short leg of the siphon (center leg of the trap) as shown in Fig. 198.

The direct action of the water of a fixture in breaking its own trap seal by siphonage, is called *self-siphonage.* A more common form of trap siphonage in defective work, is where two or more fixtures connect with the same waste pipe, as shown in Fig. 199. In such cases, the seal of the lower fixture is more apt to be broken by the discharge of the upper. The falling column of water leaves behind it a partial vacuum in the soil pipe; and the outer air tends to rush into the pipe through the way of least resistance, which is often through the trap seal of the fixture below The friction of the rough sides of a tall soil-pipe, even though it be open at the roof, opposed to the flow of air through it, will sometimes offer more resistance than the trap seals of the fixtures, with the result that the seals are broken, and gases from the drain are free to enter the building.

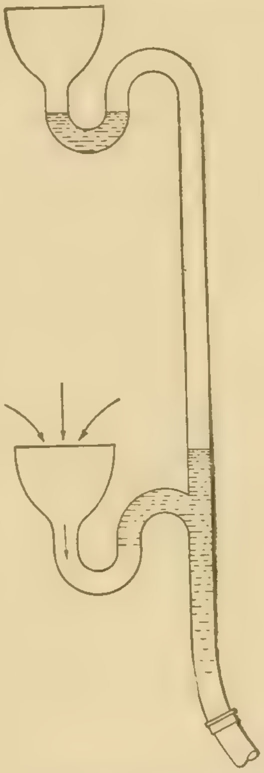


Fig. 199. Two Unvented Fixtures Connected to Same Waste Pipe, Causing Self-Siphonage.

Kinds of Traps. The kinds of fixture traps are innumerable. They can be divided into two general classes—those that seal with *water only*, and those that have a *mechanical seal* as an adjunct to that of the water. These may be again divided into *plain* and *anti-siphoning* classes.

The trap having no concealed partitions and with all its walls exposed to view, is best. If the water leaks through the wall, its defectiveness is evident, and the annoyance from the leak suggests repairing.

Of the simple *water-seal* fixture traps, the open-walled *drawn lead* is used for ordinary work. It can be had with equal-length arms or with extended inlet or outlet, so as to reach from fixture to floor or wall without a piece of intermediate pipe. The form shown by full lines in Fig. 200 represents a full "S" pattern. When the ends are bent as per dotted lines *A* and *C*, the trap is called a *running* trap; when the ends are at *D* and *C*, it is said to be a *half-S* or *P* trap; when the ends are set as at *D* and *E*, it is called a ¾-*S* trap. *F* is a clean-out screw for emptying and cleansing. The distance represented by *X* should, in a trap for ordinary purposes, be ½ to 2 inches, according to size. Frequently this distance, which constitutes the water-lock, is much reduced; and sometimes the trap is unsealed by the plumber stretching its bends in order to reach some faulty roughing-in.

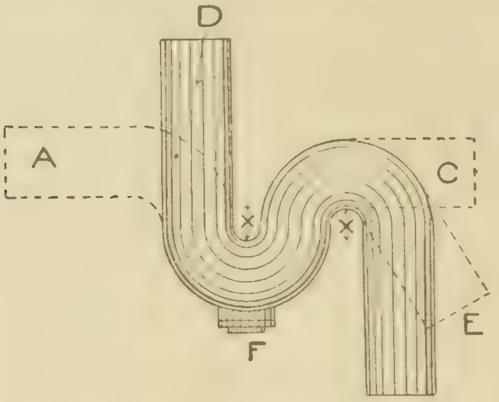


Fig. 200. "S"-Pattern Trap.

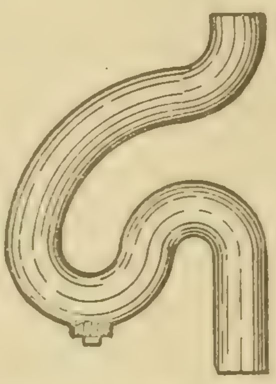


Fig. 201. A Bag Trap.

In buildings where the plumbing may be left unused for weeks from time to time, as is likely in rented houses, *deep-seal* traps, or those with mechanical seals also, should be used. This point is not so important in detached houses or those rented to one family only at a time, since, when a family moves out, there is no one to suffer. But in flat buildings, where some of the flats may be vacant for a time sufficient for an ordinary seal to be broken while other families are living in the house, deep-seal traps are more essential.

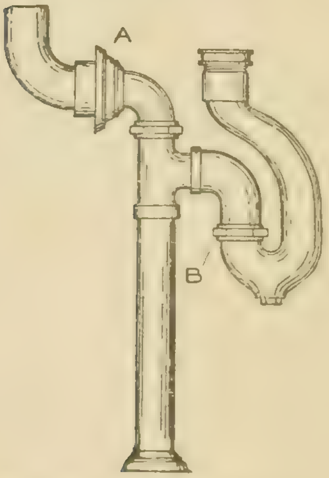


Fig. 202. Open-Wall Trap. Partly Cast.

Fig. 201 shows what is termed a *bag trap*, made to bring the inlet and outlet in the same vertical line. These traps are interchangeable with any others with straight-line outlet—for instance, as shown in Fig. 204.

An open-wall trap partly cast and partly tubing, generally made of brass, is shown in Fig. 202, the vent connection to wall being at *A*. This form of trap generally has a swivel-joint at *B*, which is below the water line, so that the body may be swiveled to meet roughing-in openings in any direction within two diameters of the line of fixture outlet. The bag form shown is most convenient for D-shape or standing waste bowls which present the outlet comparatively near the wall. The regular "S" of this type suits bowls with center outlet, and will reach a wider range of variation in roughing-in.

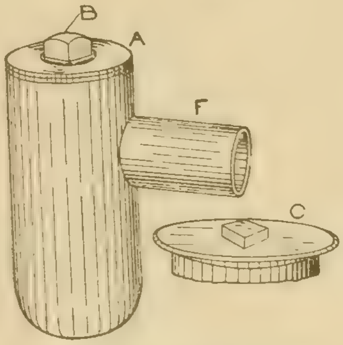


Fig. 203. Common Lead Drum or Pot Trap.

Fig. 203 shows a common lead drum or pot trap, most convenient to the plumber. It is furnished without openings, and the plumber makes bends, and wipes-in his inlet and outlet at points in the circumference most convenient to reach the fixture opening. *A* is the screw-top clean-out; and *B*, the wrench-face for turning it. The trap is furnished, when desired, with nickel-plated brass flanged cover, as shown at *C*, to screw on at the floor-level. *F* is ordinarily the outlet, the inlet being wiped-in near the bottom to give it the water-lock. This is not proper, however, as it puts the sewer air against the clean-out cover, which might leak gases into the building without betraying any evidence of its defectiveness by water leakage. To be strictly correct, *F* should be the inlet; and the outlet, in the shape of an offset, or that of an inverted P-trap without the trap-screw, should be wiped-in near the bottom in a way to retain the proper seal and thus bring the sewer air against the water-seal instead of the clean-out cover.

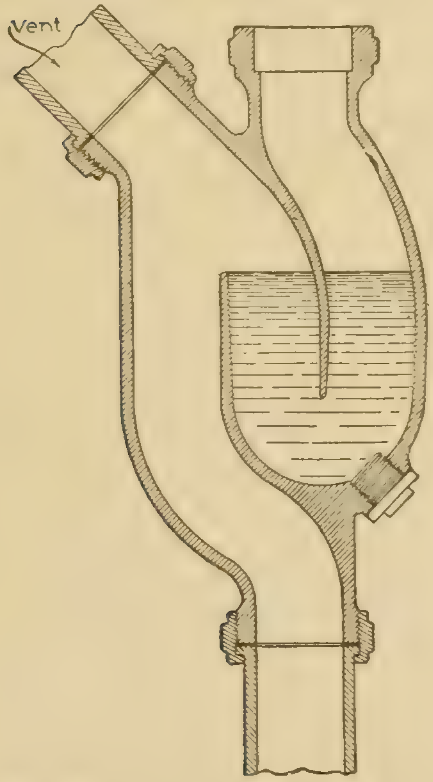


Fig. 204. Section of Flask or Atlas Trap, with Two Interior Weirs.

Traps that retain their seals by means of interior weirs are of doubtful character, even at their best; none but well-tested cast-brass traps of such a pattern should ever be installed. Fig. 204 is a section of a *flask* or *Atlas* trap, with vent, usually made of cast brass and depending upon two interior weirs to form the seal, one retaining the water, and the other dipping into the water to prevent sewer air from getting into the house through the fixture. If the water weir of such a trap becomes defective, there is no evidence except odors by which the occupants may discover it. If the dipping weir is defective the value of the water seal is *nil*. In either case the trap is no barrier to the admission of drain air to the house.

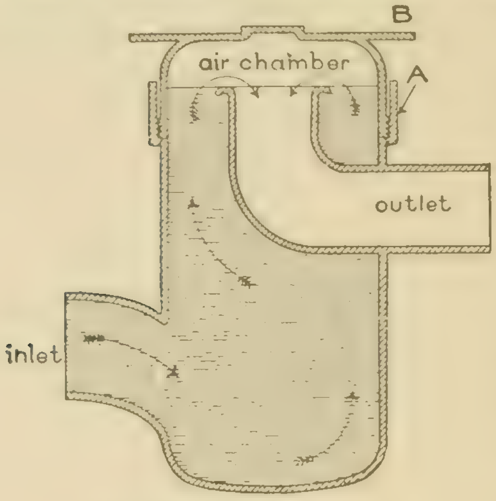


Fig. 205. Bath Trap with Submerged Inlet.

Fig. 205 illustrates a form of trap suitable for use with baths. It has a submerged inlet connection which is expanded so that the flow enters the trap at a dipping angle which produces a swirl with cleansing effect. The extension collar *A* is made so that the screw-cover *B* forms the gasket joint below the water-level. The method of providing the outlet in this trap makes it open to the same objection raised in connection with Fig. 203. This form, however, has the merit of being accessible for inspection without disturbing its service, which is impossible with the flask pattern shown in Fig. 204.

The lavatory trap shown in Fig. 206, has an interior weir as shown at *A*; but the wall is doubled in such a way as to betray defectiveness by water leakage. It is made of cast metal, and is furnished

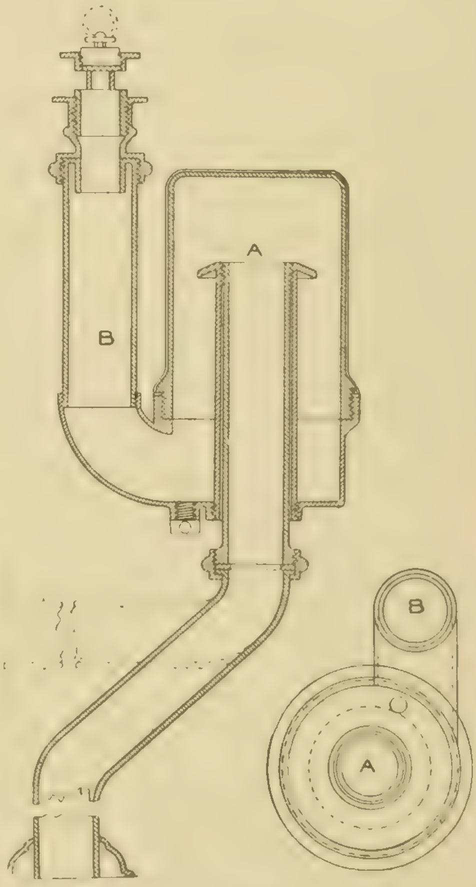


Fig. 206. Lavatory Trap with Interior Flanged Weir. Weir is Double-Walled to Betray Leakage.

with either glass or metal dome. The strong point claimed for this trap is the cleansing effect obtained by the flange extension of the exit, as shown at *A*, deflecting some of the water, which, together with the swirling effect produced by the tangential inlet, makes the trap self-cleansing.

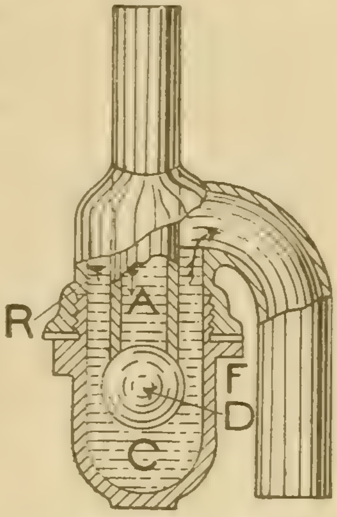


Fig. 207. Trap with Mechanical Seal Acting by Flotation.

Of the traps having a mechanical seal supplementing the water-lock, Fig. 207 is a specific type. The mechanical valve *D* is a rubber ball, lighter than an equal bulk of water, playing in the cup *C*. It acts by flotation, and presses up against the inlet *A* with a force equal to the difference in weight of the ball and the water it displaces. The body is generally made of lead; and the cup of glass, with screw-joint and gasket at *F*. This trap is proof against backwater; and, in case the waste line becomes choked below, will prevent a fixture from flooding even when others are discharged at a higher level. It has, however, several faults that counterbalance its merits. The inlet is open to the same criticisms that an interior wall of any other trap would be; the annular space at *R* accumulates filth; and the mechanical seal is worthless when most needed—that is, in the absence of the water-seal.

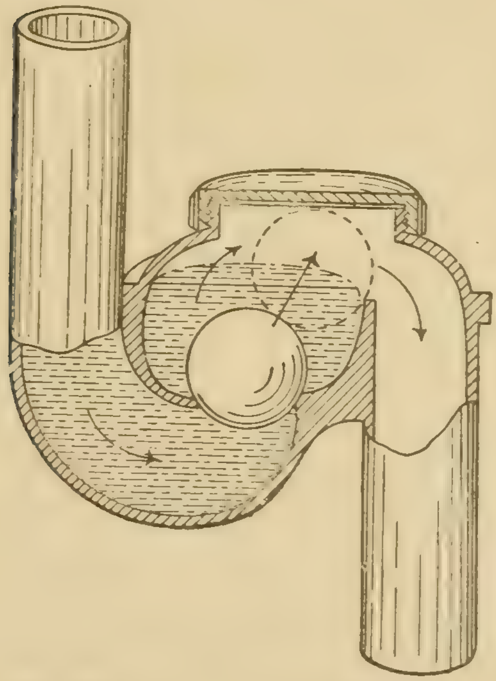


Fig. 208. Trap with Mechanical Seal Acting by Gravity.

Another mechanical seal trap, shown in Fig. 208, is the exact opposite of the previous example. The ball sinks by gravity, and effects a mechanical seal even when the water seal is absent. This trap is not so easily siphoned as a plain trap. It has a clean-out screw, and can be had with vent opening. Air from the sewer side acts against the clean-out cap through which access is had to the ball, and there are interior walls to become defective with little chance of discovery in practice.

A combined mechanical and water-seal trap is shown in Fig. 209, in which *D* is a hollow, flexible ball inclosing a metal ball D^1, thus giving a resilient seating surface that finds its place by gravity in water. The arrangement is proof against back-water, and the mechanical seal is positive without the aid of water. *A* represents the basin; *B*, the basin coupling; *C*, the valve seat; *F*, a glass cylinder body; and *GG*, a clamp with thumb-screw G^1, for clamping the cylinder body in place. This trap holds a large amount of water, and is not likely to become unsealed from lack of use, as part of the seal is protected by the ball, and should the water evaporate, the mechanical seal is still effective. There are no interior walls through which the trap could lose its seal without betraying the fact by leakage. Generally speaking, mechanical seals in fixture traps cannot be depended upon.

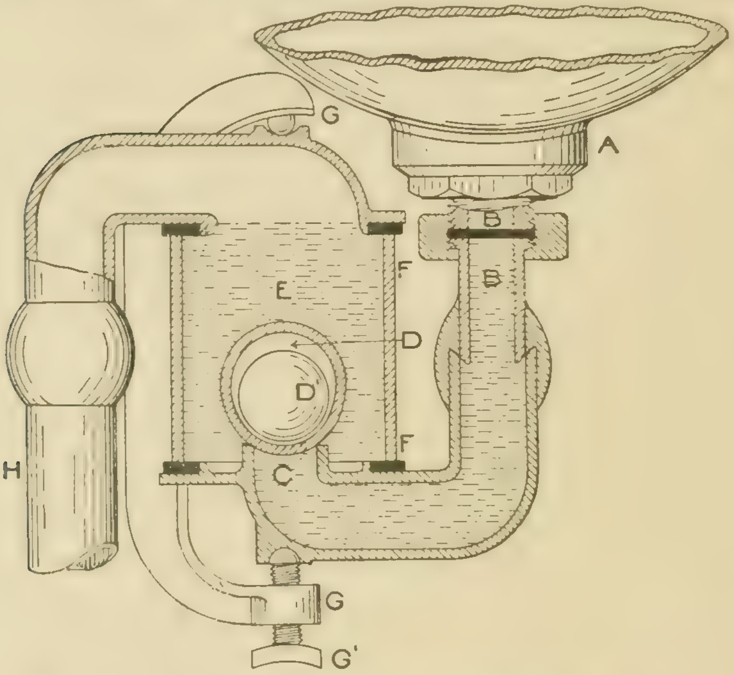
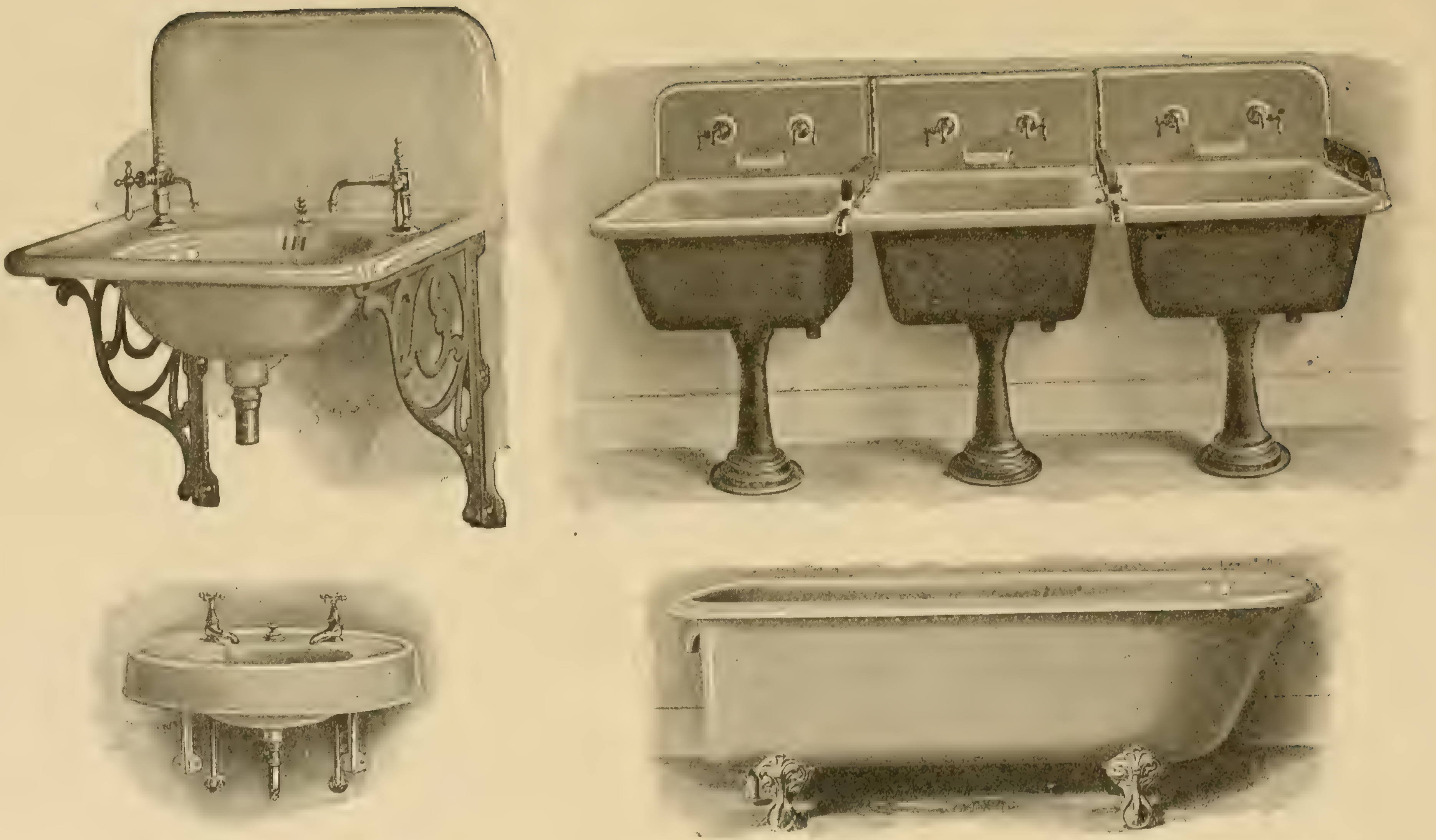


Fig. 209. Trap with Combined Water-Seal and Gravity-Acting Mechanical Seal.

Anti-siphoning traps are a blessing in instances where pipe ventilation is difficult. It would be better to have none of them, however, than to attempt to supplant pipe ventilation by their use to any great extent.

It would be impossible here to consider the whole list of traps individually in an adequate manner. What has been said should be enough to enable one by careful study to decide each case intelligently upon its merits. Many special traps are deserving of more favor than is generally shown them. It is the fear of seeming to indorse the horde of cheap competitive articles that causes many to ignore alike the good and bad. This fear is well grounded. The wolves will creep in if the door is opened at all.

Loss of Traps Seals. Traps may lose their seals in six ways—by



REPRESENTATIVE MODERN BATH ROOM AND LAVATORY FITTINGS.

waving out, by *capillary action*, by *leakage*, by *evaporation*, by *siphonage*, and—if the use of an unusual term be permissible—by *impellation*. The first, with its cause, has been described (see page 117). The last, like waving out, is caused by air-pressure, but on the house side instead of the sewer side of the trap. It occurs most frequently in intercepting traps where the fresh-air inlet has been connected too far from the trap, thus allowing heavy discharges of water and storm floods to compress the air between the fresh-air inlet and the trap. This action is of little consequence when so caused, as there is abundance of water to re-establish the seal. Its mention, however, suggests that a portion of the pipe is left unventilated by connecting the inlet too far from the trap. This error is usually made with good intention, because the foul-air outlet and fresh-air inlet are often made in the trap proper and are therefore too close together to pipe to the surface directly. There is a singular instance on record, of a trap having its seal broken by pressure on the house side—not from pressure of air in the pipe, but of that in the room into which the trap seal opened. This was a water-closet in a tight, unventilated compartment in a private house. Odors were often present which no one could account for. The job was new and first-class. The house was well built—too well. After many others had failed to diagnose the trouble, a plumber with some philosophy in his make-up examined the job. He stood in the hall, and slammed the closet-room door. It failed to latch, the room being so tight that the air-pressure kept it from seating on the rabbet of the frame. The door, of course, was instantly thrown partly open again by expansion of the air, and the plumber caught a glimpse of the water in the closet-bowl bobbing up and down. By repeating the experiment and measuring the depth of water between times, he discovered that, as suspected, the sudden closing of the door of the small, tight room was thrusting the water down in the bowl and causing enough to flow over into the soil pipe to break the seal. The trouble was remedied by cutting ½ inch off the door at the bottom.

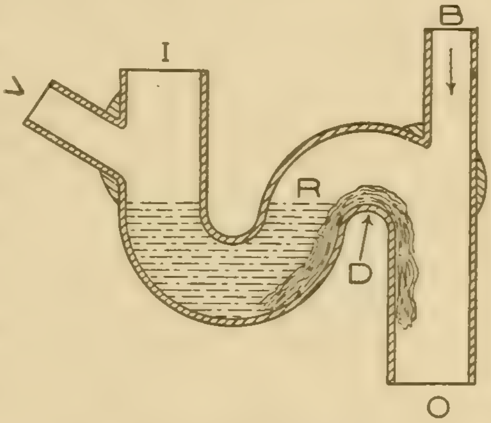


Fig. 210. Foreign Matter (Lint, Strings, etc.) Causing Capillary Loss of Trap Seal.

Evaporation has been described elsewhere. Leakage of seals has been mentioned in conjunction with types of fixture traps. Siphonage of traps is simple. The conditions necessary to start a common siphon being established in a waste pipe, the seal will be drawn out. The discharge of water from a fixture will siphon its trap (self-siphonage), if no provision against siphonage is made. The crown vent pipe, as described, breaks the siphon in a trap when its fixture is discharging, and prevents other fixtures from siphoning or waving out the seal. Capillary loss of seal occurs through hair, lint, and strings hanging over the weir of the trap. Dipping into the seal on one side, and ending in the pipe on the other, water will climb through or between such matter by capillary force, and will drip by gravity into the pipe. This is indicated by the tangled lines at *R*, Fig. 210, representing capillary material hanging over the outlet neck *D* of the trap. The trap indicated is for a lavatory with horn overflow bowl, *V* being the overflow connection, *I* the waste, *B* the crown vent, and *O* the outlet. Traps are sometimes locally vented at *V*.

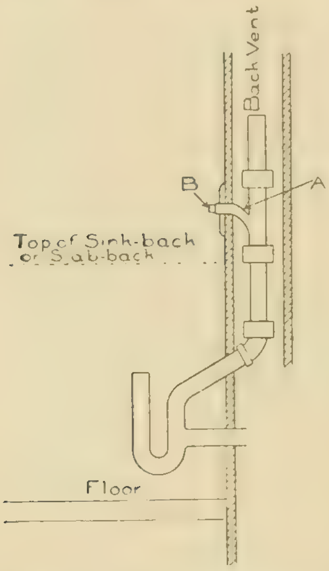


Fig. 211. Installation in which Provision is Made for Flushing and Cleaning Offset Vent Whenever Necessary.

Materials forming a porous coating on the inner walls of the trap through chemical action or otherwise, are now and then responsible for the loss of water-seal by action of a capillary nature. The shape of a trap may favor the accumulation of matter that will lead to capillary loss of seal. This is one reason why the plain, open-wall, cylindrical-bore traps are best. It is found that no matter how the trap is shaped, its surface is, as a rule, not used except at the points which conform to the simplest, most direct course—as before said. Other shapes, then, present needless fouling surface and space for accumulation of matter that interferes with the proper service of the trap. Departure from the shape mentioned is necessary to secure an unvented trap that cannot be siphoned. Any trap that must necessarily be connected so as to put the air of the sewer side against the gasket of the clean-out cap, should not be used.

A difficulty common to venting the general run of plumbing fixtures, is presented by the fact that to crown-vent the trap prohibits sufficient immediate vertical rise of the crown vent to get above the fixture overflow-level, without making an offset in the vent, which, in case of stoppage of the waste, favors choking of the vent in the offset by matter floated into it as a consequence of the stoppage. A plan providing for flushing of the vent at will, is shown in Fig. 211, a sanitary tee branch being placed in the vent above the level of the sink or lavatory back, as shown at *A*, and closed by nickel-plated trap-screw cover *B* at the face of the finished wall. In this way, by removing cover *B*, a wire can be run through to the trap-screw clean-out, and the offset portion thus cleaned; and, if necessary, it can be flushed by injecting water at *B* with a hose or funnel.

REVIEW QUESTIONS.

PRACTICAL TEST QUESTIONS.

In the foregoing sections of this Cyclopedia numerous illustrative examples are worked out in detail in order to show the application of the various methods and principles. Accompanying these are examples for practice which will aid the reader in fixing the principles in mind.

In the following pages are given a large number of test questions and problems which afford a valuable means of testing the reader's knowledge of the subjects treated. They will be found excellent practice for those preparing for College, Civil Service, or Engineer's License. In some cases numerical answers are given as a further aid in this work.

REVIEW QUESTIONS

ON THE SUBJECT OF

HEATING AND VENTILATION.

PART I.

1. What advantage does indirect steam heating have over direct heating? What advantages over furnace heating?

2. What are the causes of heat loss from a building?

3. Why is hot water especially adapted to the warming of dwellings?

4. What proportion of carbonic acid gas is found in outdoor air under ordinary conditions?

5. A room in the N. E. corner of a building of fairly good construction is 18 feet square and 10 feet high; there are 5 single windows, each 3 by 10 feet in size. The walls are of brick 12 inches in thickness. With an inside temperature of 70 degrees, what will be the heat loss per hour in zero weather?

6. State four important points to be noted in the care of a furnace.

7. A grammar school building, constructed in the most thorough manner, has 4 rooms, one in each corner, each being 30 ft. by 30 ft. and 14 ft. high, and seating 50 pupils. The walls are of wooden construction, and the windows make up $\frac{1}{5}$ of the total exposed surface. The basement and attic are warm. How many pounds of coal will be required per hour for both heating and ventilation in zero weather, if 8,000 B. T. U. are utilized from each pound of coal?

8. What two distinct types of furnaces are used? What are the distinguishing features?

9. What is meant by the efficiency of a furnace? What efficiencies are obtained in ordinary practice?

10. What are the principal parts of a furnace? State briefly the use of each.

11. A brick house of the best construction, 20 ft. by 40 ft., has 3 stories, each 10 feet high. The walls are 12 inches in thickness; and $\frac{1}{4}$ the total exposed wall is taken up by windows, which are double. The basement is warm, but the attic is cold. The house is to be warmed to 70 degrees when it is ten degrees below zero outside. How many square feet of grate surface will be required, assuming usual efficiencies of coal and furnace?

12. A high school is to be provided with tubular boilers. What H. P. will be required for warming and ventilation in zero weather if there are 600 occupants, and the heat loss through walls and windows is 1,500,000 B. T. U. per hour?

13. What are the three essential parts of any heating system?

14. Is direct-steam heating adapted to the warming of schoolhouses and hospitals? Give the reason for your answer.

15. The heat loss from a dwelling-house is 280,000 B. T. U. per hour. It is to be heated with direct steam by a type of sectional boiler in which the ratio of heating surface to grate surface is 28. What will be the most efficient rate of combustion, and how many square feet of grate surface will be required?

16. What is the use of a blow-off tank? Show by a sketch how the connections are made.

17. How are the sizes of single-pipe risers computed?

18. What weight of steam will be discharged per hour through a 6-inch pipe 300 feet long, with an initial pressure of 10 pounds, and a drop of $\frac{3}{4}$ pound in its entire length?

19. What is an air-valve? Upon what principles does it work?

20. What size of steam pipe will be required to discharge 2,400 pounds of steam per hour a distance of 900 feet, with an initial pressure of 60 pounds, and a drop in pressure of 5 pounds?

21. What objection is there to a single-pipe riser system? How is this sometimes overcome in large buildings?

22. What patterns of valves should be used for radiators? What conditions of construction must be observed in making the connections between the radiator and riser?

23. The heat loss from a shop is 36,000 B. T. U. per hour; how

many linear feet of 2-inch pipe will be required to warm it, using low-pressure steam?

24. What are meant by wet and dry returns? Which is the better, and why?

25. How many linear feet of 1¼-inch pipe are required to give off the same amount of heat as a cast-iron radiator having 125 square feet of surface?

26. What three systems of piping are commonly used in direct-steam heating? Describe each briefly.

27. What is a *branch coil*? What is a *trombone coil*? In what cases would you use a trombone coil instead of a branch coil?

28. What is meant by the efficiency of a radiator? Give average efficiencies of cast-iron and pipe radiators; also of circulation coils, both wall and ceiling.

29. The heat loss from a room is 22,500 B. T. U. in zero weather. What size of cast-iron radiator would be required to warm the room when it is twenty degrees below zero?

30. Where would you place the direct radiation in a schoolroom?

REVIEW QUESTIONS

ON THE SUBJECT OF

HEATING AND VENTILATION.

PART II.

1. How would you obtain the sizes of the cold-air and warm-air pipes connecting with indirect heaters in dwelling-house work?

2. What is an aspirating coil, and what is its use?

3. What efficiencies may be allowed for indirect heaters in schoolhouse work? How would you compute the size of an indirect heater for a room in a dwelling-house?

4. How is the size of a direct-indirect radiator computed?

5. A schoolroom on the third floor is to be supplied with 2,400 cubic feet of air per minute. What should be the area of the warm-air supply flue?

6. What is the chief objection to a mixing damper, and how may this be overcome?

7. How many square feet of indirect radiation will be required to warm and ventilate a schoolroom when it is 10 degrees below zero, if the heat loss through walls and windows is 42,000 B. T. U., and the air-supply 120,000 cubic feet per hour?

8. What is the difference in construction oetween a steam radiator and one designed for hot water? Can the steam radiator be used for hot water? State reasons for answer.

9. How may the piping in a hot-water system be arranged so that no air-valves will be required on the radiators?

10. What efficiency is commonly obtained from a direct hot-water radiator? How is this computed?

11. How should the pipes be graded in making the connections with indirect hot-water heaters?. Where should the air-valve be placed?

12. Describe briefly one form of grease extractor.

13. What is the office of a pressure-reducing valve in an exhaust-steam heating system?

14. Upon what principle does a pump governor operate?

15. What type of pipe fittings should always be used in hot-water work?

16. How is the water of condensation returned to the boilers in exhaust steam heating?

17. How many cubic feet of air per hour will be discharged through a flue 2 feet by 3 feet, and 60 feet high, if the air in the flue has a temperature of 80 degrees and the outside air 60 degrees?

18. In a hot-water heating system, what causes the water to flow through the pipes and radiators? How does the height of the radiator above the boiler affect the flow?

19. What precaution should always be taken before starting a fire under a steam boiler?

20. What is the free opening in square feet through a register 24 inches by 48 inches?

21. Why are return pumps or return traps necessary in exhaust-steam heating plants?

22. What efficiency may be obtained from indirect hot-water radiators under usual conditions? What is the common method of computing indirect hot-water surface for dwelling-house work?

23. State briefly how a return trap operates.

24. What is the use of an expansion tank, and what should be its capacity?

25. Describe the action of one form of damper regulator.

26. What is the principal difference between a hot-water heater and a steam boiler? What type of heater is best adapted to the warming of dwelling-houses?

27. Upon what four conditions does the size of a pipe to supply any given radiator depend?

28. What is the use of an exhaust head?

29. A hospital ward requires 60,000 cubic feet of air per hour for ventilation, and the heat loss through walls and windows is 140,000 B. T. U. per hour. How many square feet of indirect steam radiation will be required in zero weather?

30. For what purpose is a back-pressure valve used?

31. A hospital ward is warmed by direct steam heat, and it is desired to add ventilation by using indirect radiators for warming the air-supply. The ward has 20 occupants. How many square feet of indirect surface will be required when it is 10 degrees below zero, allowing an efficiency of 660?

32. A first-floor classroom in a high school has 40 pupils. How many square feet area should the vent flue have?

33. A private grammar school room having 15 pupils is heated by direct hot water. It is decided to increase the size of boiler and to introduce ventilation by means of indirect hot-water radiation. How many more square feet of grate surface will be required in the new boiler for zero weather?

34. What are some of the methods employed for the general air-venting of a system of hot-water heating?

35. The rooms in a certain corner of a 10-story office building are of uniform size on each floor. The building is heated with direct hot water, having an overhead distribution. The series of rooms mentioned are heated from a single supply drop, and the return from each radiator is connected into the same drop. If the room on the 10th floor requires a radiator having 100 square feet of surface, what should be the size of the radiator on the first floor?

36. A building contains 40,000 square feet of direct radiation, and is to be heated with forced hot-water circulation. The circuit main is 500 feet in length and has 10 long-turn elbows. Assuming a drop in temperature of 40°, a velocity of flow of 480 ft. per minute, and a friction head of between 30 and 40 feet, what size of main will be required, and what horse-power will be required to drive the pump?

REVIEW QUESTIONS

ON THE SUBJECT OF

HEATING AND VENTILATION.

PART III.

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1. A main heater contains 1,040 square feet of heating surface made up of wrought-iron pipe, and is used in connection with a fan which delivers 528,000 cubic feet of air per hour. The heater is 20 pipes deep, and has a free area, between the pipes, of 11 square feet. If air is taken at zero, to what temperature will it be raised with steam at 5 pounds' pressure.

2. An 8-foot fan used for schoolhouse ventilation runs at a speed of 124 r. p. m. What horse-power of engine is required? What horse-power would be required if the fan were speeded up to 134.6 r. p. m.?

3. What precaution must be taken in connecting the radiators in tall buildings?

4. Give the size of heater from Table XXXI which will be required to raise 672,000 cubic feet of air per hour, from 10° below zero to 95°, with a steam pressure of 20 pounds. If the air-quantity is raised to 840,000 cubic feet per hour through the same heater, what will be the resulting temperature with all other conditions the same?

5. A fan running at 150 revolutions produces a pressure of $\frac{1}{2}$ ounce. If the speed is increased to 210 revolutions, what will be the resulting pressure?

6. A certain fan is delivering 12,000 cubic feet of air per minute, at a speed of 200 revolutions. It is desired to increase the amount to 18,000 cubic feet. What will be the required speed? If the original power required to run the fan was 4 H. P., what will be the final power due to the increased speed?

7. What size fan will be required to supply a schoolhouse

having 300 pupils, if each is to be provided with 3,000 cubic feet of air per hour? What speed of fan will be required, and what H. P. of engine?

8. What advantages has the plenum method of ventilation over the exhaust method?

9. A church is to be warmed and ventilated by means of a fan and heater. The air-supply is to be 300,000 cubic feet per hour. The heat loss through walls and windows is 200,000 B. T. U., when it is zero. How many square feet of heating surface will be required, and how many rows of pipe deep must the heater be, with steam at 5 pounds' pressure?

10. A schoolhouse requiring 600,000 cubic feet of air per hour is to be supplied with a cast-iron sectional heater of the pin type. How many square feet of radiating surface will be required to raise the air from 10° below zero to 70° above, with a steam pressure of 10 pounds?

11. What velocities of air-flow in the main duct and branches are commonly used in connection with a fan system?

12. A main heater is to be designed for use in connection with a fan. How many square feet of radiation will be required to warm 1,000,000 cubic feet of air per hour, from a temperature of 10° below zero to 70° above, with a steam pressure of 5 pounds and a velocity of 800 feet per minute between the pipes of the heater? How many rows of pipe deep must the heater be?

13. State in a brief manner the essential parts of a system of automatic temperature control.

14. What advantage does an indirect steam-heating system have over furnace heating in schoolhouse work?

15. The air in a restaurant kitchen is to be changed every 10 minutes by means of a disc fan. The room is 60 by 30 by 10 feet. Give size and speed of fan, and H. P. of motor.

16. What forms of heating are best adapted to the warming of apartment houses?

17. Give an approximate method for finding the heating surface required for greenhouses, both for steam and hot water.

18. How does the cost of electric heating compare with that by steam and hot water?

19. Describe briefly the construction of an electric heater, and the principle upon which it works.

20. A school building of 4 rooms is to be supplied with 600,000 cubic feet of air per hour. The heat loss from the building is 300,000 B. T. U. per hour in zero weather. Give the square feet of grate surface required in the furnaces.

21. What is a double-duct system as applied to forced-blast heating? What are its advantages?

22. What is a thermostat? Give the principles upon which two different kinds operate.

23. Describe briefly the connections to be made in a system of electric heating. In what way do they correspond to the piping in a system of steam heating?

24. State certain points to be observed in the introduction of air for the ventilation of churches and theaters.

25. A shop 100 feet long, 50 feet wide, and having 5 stories, each 10 feet high, is to be warmed by forced blast using steam at 80 pounds' pressure. The full amount of air passed through the heater is to be taken from out of doors, and the entire air of the building changed 3 times an hour. Give linear feet of 1-inch pipe required for heater, and size of fan and engine.

26. In what cases would you use a disc fan in preference to a blower?

27. The heat loss from a room is 12,000 B. T. U. per hour. How many kilowatt-hours will be required to furnish the necessary heat?

28. What is one of the best systems for the heating and ventilation of school buildings of large size?

29. What form of heating system would you recommend for a four-room school?

30. A factory 250 feet long by 50 feet wide has two stories, each 10 feet high. Each floor is to have a separate fan and heater, but the fans are to be driven by the same electric motor. The lower floor is to be supplied with air from out of doors, and is to have a complete change of air every 20 minutes. On the upper floor the air is to be returned to the heater from the room, and the entire contents is to pass through the heater every 20 minutes. Exhaust steam is to be used in both heaters. Give sizes of fans, heaters, and motor.

31. What is a telethermometer?

32. Describe two methods of moistening air.

REVIEW QUESTIONS

ON THE SUBJECT OF

PLUMBING.

PART I.

1. Under what conditions is a spring of water available for house supply?

2. What methods are adopted of supplementing municipal service in case of insufficient pressure?

3. What are the essential requirements of a good laundry tray?

4. What do you consider the poorest types of water-closets?

5. What are the general methods of supplying buildings with water?

6. How far should the bottom of a cistern be below the cylinder of an ordinary house suction pump?

7. How is *siphonic eduction* effected in the case of range closets? Illustrate by diagram.

8. Describe the part played by lead in modern plumbing.

9. What is a *pneumatic siphon* closet? Give diagram.

10. How can an open-trough range closet be satisfactorily ventilated?

11. How can supply to tanks be automatically regulated?

12. When is a hydraulic ram available for house supply?

13. Describe the various kinds of bathtub supply and waste fittings.

14. What are the advantages or disadvantages of the *combined hopper and trap* and the *wash-out* types of closets? Illustrate by freehand sketches.

15. Classify bathtubs (1) according to material; (2) according to shape. Illustrate the shapes by freehand sketches. Discuss the relative merits of the different classes of bathtubs.

REVIEW QUESTIONS

ON THE SUBJECT OF

PLUMBING.

PART II.

1. Describe the essential features of a stove or range connection of a reservoir.

2. Explain the principle of the Bunsen burner. What application does it have in connection with lighting by gas?

3. How many square feet of heating surface will be needed in a submerged brass coil filled with steam at 7 pounds' pressure, to raise the temperature of 125 gallons of water per hour from 40 degrees to 200 degrees?

4. What is the cause of rumbling in a reservoir?

5. What is the object of the siphon hole in the delivery pipe in a reservoir?

6. Describe the different classes of filters?

7. Draw a diagram showing connections of hot-water reservoir (1) to a single water-back; (2) to two water-backs on different floors.

8. Explain the function of the air-chamber in a force pump.

9. A house usually settles after being built. If rigid iron service pipes are used, how can the effects of settling be avoided?

10. How are service pipes protected from frost?

11. How many square feet of grate surface will be needed to raise 150 gallons of water per hour from 45 degrees to one of 160 degrees?

12. What rules should be observed in making bends in pipes?

13. What are the salient features of the direct system of supply?

14. Explain the working of a common suction pump. Illustrate by diagram.

15. Name and describe five kinds of gas burners for lighting purposes.

16. When is a lift pump necessary? How does it differ from an ordinary suction pump?

17. In case of temporary stoppage of supply, what precautions should be taken?

REVIEW QUESTIONS

ON THE SUBJECT OF

PLUMBING.

PART III.

1. Describe two types of mechanical-seal traps.

2. Draw rough sketches showing how ventilating loop can be secured (1) when crown vent stack and waste stack stand close together; (2) when these stacks are a considerable distance apart; (3) when neither stack stands near the fixture.

3. Under what conditions would you recommend the use of anti-siphon traps in solving the problem of ventilation?

4. What is meant by the "loop" plan in installation of waste and vent stacks?

5. How are joints made between wrought-iron and cast-iron soil-pipe?

6. Explain the principle of the anti-siphon trap.

7. What considerations determine the size of soil and waste pipes? What would you consider proper sizes for a single dwelling with two closets (1 in basement and 1 on second floor), and with 1 bath, 1 sink, 1 lavatory, and 2 laundry trays?

8. When stacks lead through roof to open air, how is closure of their ends by hoar frost prevented?

9. When fixtures are scattered, how can the necessity for separate stacks be avoided?

10. Under what general heads are traps classified? Illustrate by diagrams (1) A running trap; (2) "S" trap; (3) "P" trap; (4) "¾-S" trap; (5) Bag trap; (6) "Pot" trap.

11. What is meant by local ventilation? Explain by diagram.

12. How may traps lose their seals?

13. How can danger of puffing of soil air from fresh-air inlet be avoided? Give sketch.

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GENERAL INDEX

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